TAXONOMY OF ORDOVICIAN OSTRACODES FROM WESTERN NEWFOUNDLAND, ANTICOSTI ISLAND AND THE ST. LAWRENCE LOWLANDS OF QUÉBEC

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TAXONOMY OF ORDOVICIAN OSTRACODES FROM WESTERN NEWFOUNDLAND, ANTICOSTI ISLAND AND THE ST. LAWRENCE LOWLANDS OF QUÉBEC

by

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ABSTRACT

The results of an investigation of Middle and Upper Ordovician ostracodes from southeastern Canada are reported. Sixty-two samples were collected from the Table Head and Long Point groups, western Newfoundland, the Jolliet Group, Anticosti Island, and the Trenton Group, St. Lawrence Lowlands. These yielded over 2600 moderately to well-preserved ostracodes. The Carter Collection, an existing collection of ostracodes from the Lowlands, was also examined. During the research, a series of difficulties were encountered in obtaining the faunas, interpreting their taxonomy, and understanding their paleoenvironmental implications.

In the sections studied, Ordovician ostracodes occurred sporadically and were often rare or absent. All the collections were obtained by washing soft shales or by vibra-tool preparation of indurate limestones; selection of samples that can be readily processed is essential. Ordovician ostracode taxonomy is often confusing; many species are narrowly defined and allow little morphological variation. In this study, the taxonomy of a number of species is revised and a number of existing species are re-interpreted as synonyms. Fifty-four species representing forty genera are described and illustrated. No new species are established, because the current species are either already described in the literature, or could only be identified at the generic level because of a lack of well-preserved material.

Although faunal composition, abundance and diversity are directly influenced by the paleoenvironment, it is difficult to develop ostracode-based criteria for the elucidation of Ordovician paleoenvironments. Observations made during this study indicate that sea-level changes and water depth were strong controls on the nature of Ordovician ostracode faunas. In the Lourdes Formation, western Newfoundland and the Ellis Bay Formation, Anticosti Island, marked increases in faunal diversity and the

rates of speciation can be directly correlated with transgressive events that increased the shelf area and the variety of niches available. Water depth, through its control of a variety of interdependent ecological factors, such as water temperature, food supply and substrate, was also an important influence on the type of ostracode community present. A series of depth-related communities are tentatively recognised. High-energy, nearshore environments tend to have a high-abundance, low-diversity fauna consisting of large, robust, smooth ostracodes; speciation rates are low and the community structure is relatively stable. Stable, open shelf, carbonate environments tend to have high-diversity faunas, consisting of a wide variety of ornamented forms such as *Eurychilina subradiata* and *Foramenella phippsi*; speciation rates are high and the community structure frequently changes. Outer shelf to shelf-slope environments tend to have a low-diversity, low-abundance fauna consisting of drepanellids such as *Warthinia nodosa* and smooth-elongate ostracodes like *Phelobythocypris cylindrica*; speciation rates are low and the community structure is stable. As depth increases and the shelf-slope transition is crossed, faunal abundance and diversity diminish rapidly and *in situ* ostracode faunas disappear altogether.

Effective use of Ordovician ostracodes as biostratigraphic indicators, depends on their ability to cross facies and provincial boundaries. At present it is not possible to make more than crude correlations, because the faunas are not well enough known. A few of the species, such as *Eurychilina subradiata* and *Tetradella quadrilirata*, are wide ranging and have obvious potential for correlating Ordovician shelf sediments. Many other species cannot be used for inter- or intra-regional correlation, because they are locally endemic, occurring in some areas, but not in others.

Key words: Ostracodes, Ordovician, Taxonomy, Newfoundland, Québec.

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CHAPTER 1

INTRODUCTION

INTRODUCTORY REMARKS

Ostracodes are studied for three main reasons: simple curiosity, their value as paleoenvironmental indicators and their biostratigraphic potential. Ordovician ostracodes are of particular interest because they are poorly known and have been under-utilised as sources of paleoecologic and biostratigraphic information.

This thesis describes Ordovician ostracode faunas from western Newfoundland, Anticosti Island and the St. Lawrence Lowlands of Québec. These faunas are not well known, and only the faunas of Anticosti Island have been published in detail. Thus, the main aim of this study was to find out what these faunas are like and develop an understanding of their taxonomy. Such an understanding is critical, since any further faunal research, either paleoenvironmental or biostratigraphic, is only as good as the

taxonomy it is based on. Although the thesis is primarily taxonomic, it also includes sections on faunal paleoecology, provincialism and biostratigraphy.

PURPOSE AND SCOPE OF THE STUDY

As this project progressed its aims changed and developed; originally the objective was to investigate the taxonomy and paleoecology of the ostracode faunas of the Long Point Group, western Newfoundland. The Long Point Group was chosen because it was known to contain ostracodes (Copeland and Bolton 1977), and it was thought that the variety of depositional settings (Fåhræus 1973) represented in the group would allow an assessment of the paleoenvironmental controls on its ostracode faunas. It was hoped that large numbers of specimens would be obtained from a variety of lithofacies, so that a series of qualitative and quantitative ostracode-based criteria for the elucidation of Ordovician paleoenvironments could be developed.

Unfortunately, the samples collected from the Long Point Group yielded relatively few ostracodes, so the project was extended to encompass faunas from the Table Head Group, western Newfoundland, Anticosti Island and the St. Lawrence Lowlands of Québec. Extending the study enabled a more comprehensive investigation and revision of the taxonomy of the Ordovician ostracode faunas of southeastern Canada to be undertaken. The previously described faunas of Anticosti Island and the St. Lawrence Lowlands are readdressed in the light of improved understanding (e.g., Foster and Kaesler 1983) of the extent to which specific morphology varies with environment. Besides investigating the taxonomy of Middle and Upper Ordovician ostracodes, this study attempts to: (a) improve current knowledge of the paleoecology of the faunas, and (b) obtain as much paleoenvironmentally useful information from

the faunas as possible. The final aim of the study was to present a summary and review of what is already known about Ordovician ostracodes.

REGIONAL GEOLOGICAL SETTING

Southeastern Canada is made up of the following elements: Grenville Basement, the St. Lawrence Platform, the Appalachian Orogen and a series of late Paleozoic successor basins (Fig. 1).

Grenville Basement.- The Laurentian craton consists of crystalline gneissic basement of Grenvillian age (about 1000 Ma).

St. Lawrence Platform.- Unconformably overlying basement rocks of the Laurentian craton is a cover sequence that forms the St. Lawrence Platform. This latest Precambrian to lower Paleozoic platformal sequence (Fig. 1) is dominated by sheet-like, shallow marine sandstones and carbonates. The boundary between the undeformed rocks of the St. Lawrence Platform and the deformed rocks of the Appalachian Orogen is taken at the Appalachian structural front.

Appalachian Orogen.- The Appalachian Orogen is a polyorogenic mountain belt that extends along the eastern margin of the Laurentian craton; the mainly Paleozoic rocks of the Orogen have been affected by the combined effects of faulting, folding, metamorphism and plutonism. Besides the obvious structural contrasts, rocks of the Orogen are thicker and of deeper water origin than those of the Platform.

For over a century the Appalachian Orogen was believed to be the outcome of deformation and uplift of a fixed geosyncline. With the advent of plate tectonics, the

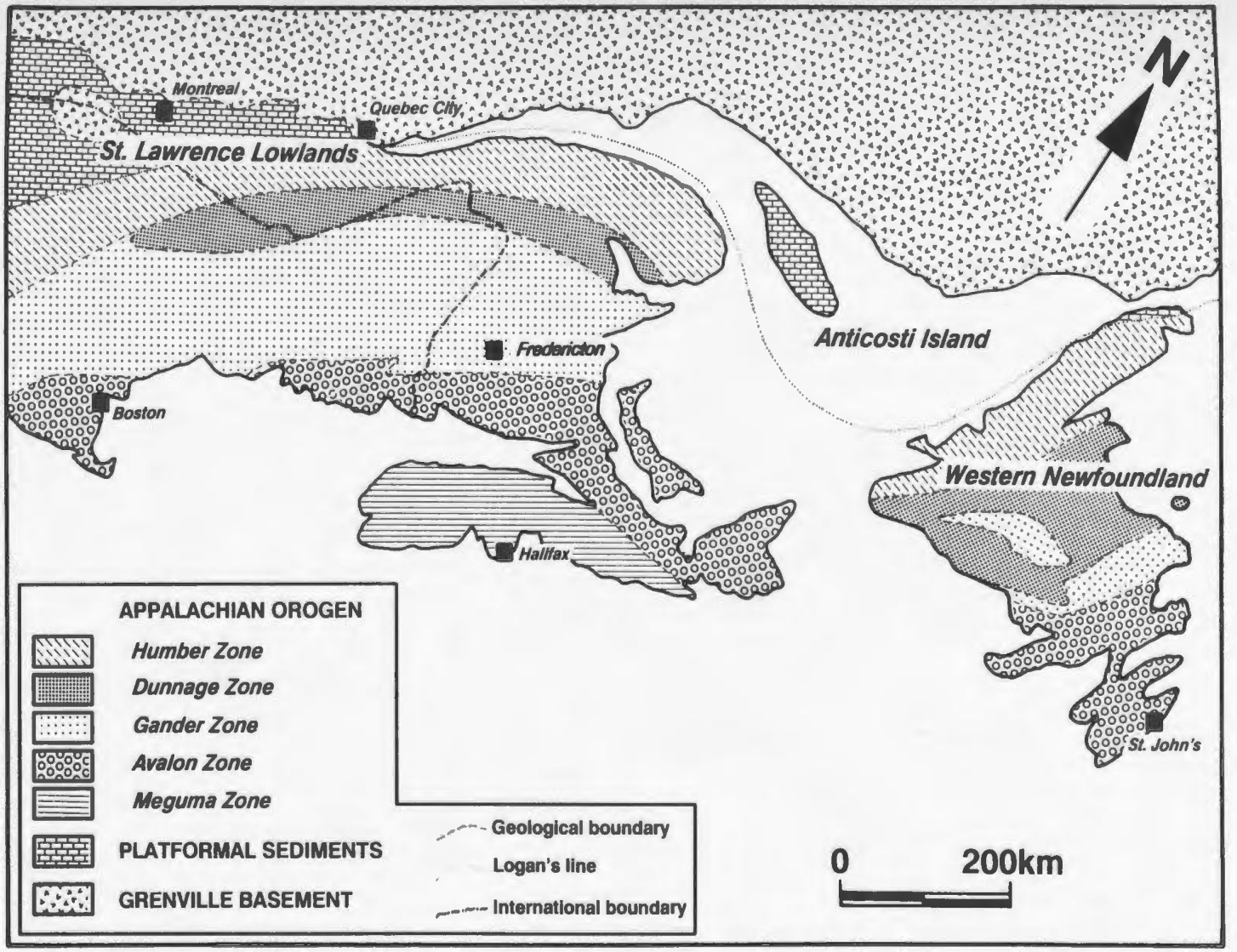


Fig. 1. Geological sketch map of southeastern Canada, showing the three study areas, western Newfoundland, Anticosti Island and the St. Lawrence Lowlands of Québec, (after Williams 1978a, Globensky 1987 and Colman-Sadd *et al.* 1990).

Orogen is now viewed as the result of ocean opening and closing during a Wilson Cycle. Dewey (1969) and Bird and Dewey (1970) developed the first plate tectonic models for the Orogen; they traced the development of the miogeocline from rifted lapetan margin, through stable passive margin to its final collisional destruction.

Williams (1976, 1978, 1979) has divided the Appalachian Orogen into five major lithotectonic zones, which are from west to east the Humber, Dunnage, Gander, Avalon and Meguma zones (Fig. 1). The Humber Zone or Appalachian miogeocline is regarded as the lower Paleozoic passive margin of the Laurentian craton, while the successively outboard zones are interpreted as suspect terranes (Williams and Hatcher 1982, 1983) that were accreted during three orogenic events that occurred during the Lower to Middle Ordovician (Taconian), Siluro-Devonian (Acadian) and Carboniferous (Alleghanian).

Anticosti Basin.- The Anticosti Basin is part of the eastern St. Lawrence Platform. Because of its location to the north of the Appalachian structural front and on the St. Lawrence promontory, the Anticosti paleoplatform was largely unaffected by the development of the Appalachian Orogen.

Late Paleozoic successor basins.- During the late Paleozoic (Carboniferous to Permian), terrestrial sediments accumulated in a series of intermontane basins along the Appalachian Orogen. These basins underlie large areas of southeastern Canada, and are collectively known as the Maritimes basins.

Age and correlation.- The correlations Barnes *et al.* (1981) made between western Newfoundland, Anticosti Island and the St. Lawrence Lowlands are illustrated in Fig. 2. The chronostratigraphic subdivisions of the Ordovician System in general, and the Champlainian Series in particular, are in a state of flux and are currently being

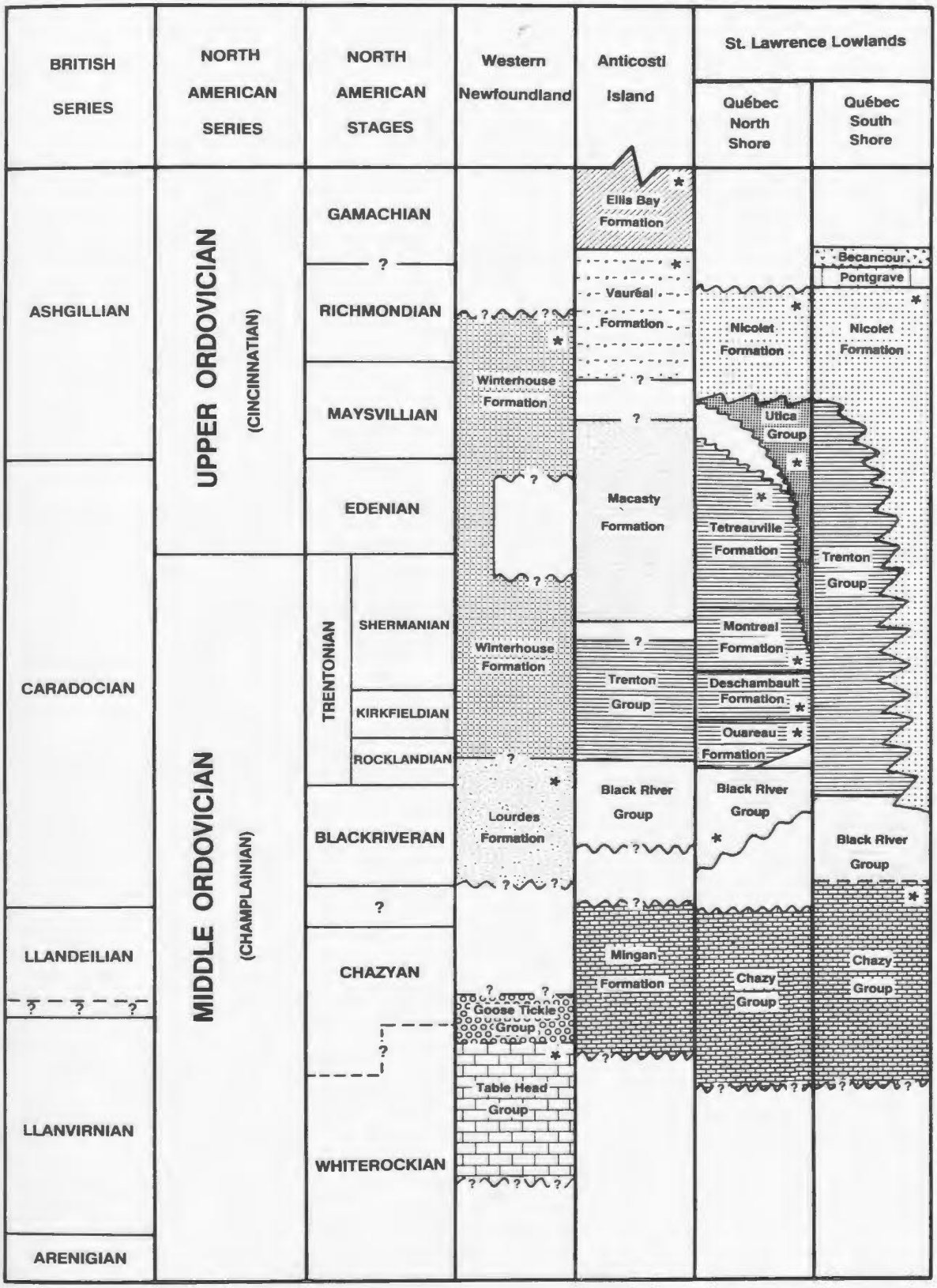


Fig. 2. Chart showing correlations between the Ordovician rocks of western Newfoundland, Anticosti Island and the St. Lawrence Lowlands of Québec, (after Barnes *et al.* 1981). Stratigraphic units marked with an asterix (★) were sampled.

revised by The Subcommission on Ordovician Stratigraphy (C.R. Barnes, personal communication, 1988). Until Middle and Upper Ordovician stage boundaries are firmly fixed in North America, this author follows the stadial nomenclature used by Barnes *et al.* (1981).

CHAPTER 2

GEOLOGICAL SETTING

WESTERN NEWFOUNDLAND

REGIONAL GEOLOGY

Introduction.- The Humber Zone and the adjoining St. Lawrence Platform were formed in an early Paleozoic, low latitude miogeocline that lay along the northern margin of the Iapetus Ocean (James *et al.* 1989). This miogeocline was the early Paleozoic passive margin of Laurentia, that was destroyed during closure of the Iapetus Ocean. The Laurentian passive margin was dominated by an extensive carbonate shelf, the outer margin of which is now exposed in western Newfoundland. This outer platform is made up of two elements: autochthonous, essentially undeformed, shallow-water sediments and westwardly transported, deep-water rocks

that were emplaced onto the platform during the Taconian Orogeny (Williams and Stevens 1974).

The western Newfoundland carbonate platform has been studied extensively and its general attributes have been recorded by Schuchert and Dunbar (1934), Rodgers (1968), Stevens (1970), Williams and Stevens (1974), James and Stevens (1982) and James *et al.* (1988, 1989). Geological maps by Williams and Cawood (1989) and Colman-Sadd *et al.* (1990) provide the most up-to-date overview of the geology of western Newfoundland.

Autochthonous rocks.- The development of the Laurentian passive margin was initiated by rifting and block-faulting of the Grenvillian basement. Unconformably overlying this irregular basement topography are siliciclastics and minor volcanics of the latest Precambrian to Lower Cambrian Labrador Group (Cumming 1983). The rift-drift transition (Williams and Hiscott 1987) and the initiation of the Iapetus Ocean was marked by the development of a narrow, high-energy, carbonate platform (James *et al.* 1989), on which peritidal carbonates of the Middle to Upper Cambrian Port au Port Group (Chow 1985) were deposited. With continued continental drift the platform changed character, becoming wider and lower energy. At about the Cambro-Ordovician boundary the style of sedimentation changed dramatically (James *et al.* 1989), and widespread muddy carbonates of the Lower Ordovician St. George Group (Knight and James 1987) began to accumulate. Carbonates of the succeeding early Middle Ordovician Table Head Group (Klappa *et al.* 1980), record the collapse and cannibalization of the long-lived carbonate platform in response to the initiation of the Taconian Orogeny (Klappa *et al.* 1980; Stenzel *et al.* 1990).

Allochthonous rocks.- In western Newfoundland, the autochthonous succession is overlain by a series of westwardly transported Taconian thrust complexes known as

the Humber Arm and Hare Bay allochthons. These thrust complexes are made up of an imbricate stack of thrust slices that consist of coeval deep-water sediments of the Cow Head (Kindle and Whittington 1958; James and Stevens 1986) and Curling (Stevens 1970) groups, together with ophiolites of the Bay of Islands Complex (Williams 1975).

Syn-orogenic flysch.- During allochthon emplacement, the foundered platform was rapidly buried by northeasterly derived syn-orogenic flysch of the Goose Tickle Group (Stenzel *et al.* 1990; Quinn, *in prep.*). In western Newfoundland, understanding of this burial phase is complicated by both syn-orogenic platform cannibalization and syn-sedimentary thrusting accompanying flysch deposition (James *et al.* 1989).

Post-orogenic sediments.- The first phase of post-Taconian sedimentation is marked by deposition of the mid-Middle to Upper Ordovician Long Point Group (Bergström *et al.* 1974). Carbonates and clastics of the Long Point Group, together with their equivalents in the subsurface of Anticosti Island (Roliff 1968), represent a renewed phase of sedimentation on the relatively low relief of the foundered and deformed lapetan margin (James *et al.* 1989).

Study areas in western Newfoundland.- Samples for ostracode preparation were collected from the autochthonous Table Head Group at Table Point (Fig. 3) and the neoautochthonous Long Point Group at Long Point (Fig. 3). At Table Point (Fig. 5), the Table Point and Table Cove formations were sampled, while at Long Point (Fig. 6), the Lourdes and Winterhouse formations were sampled.

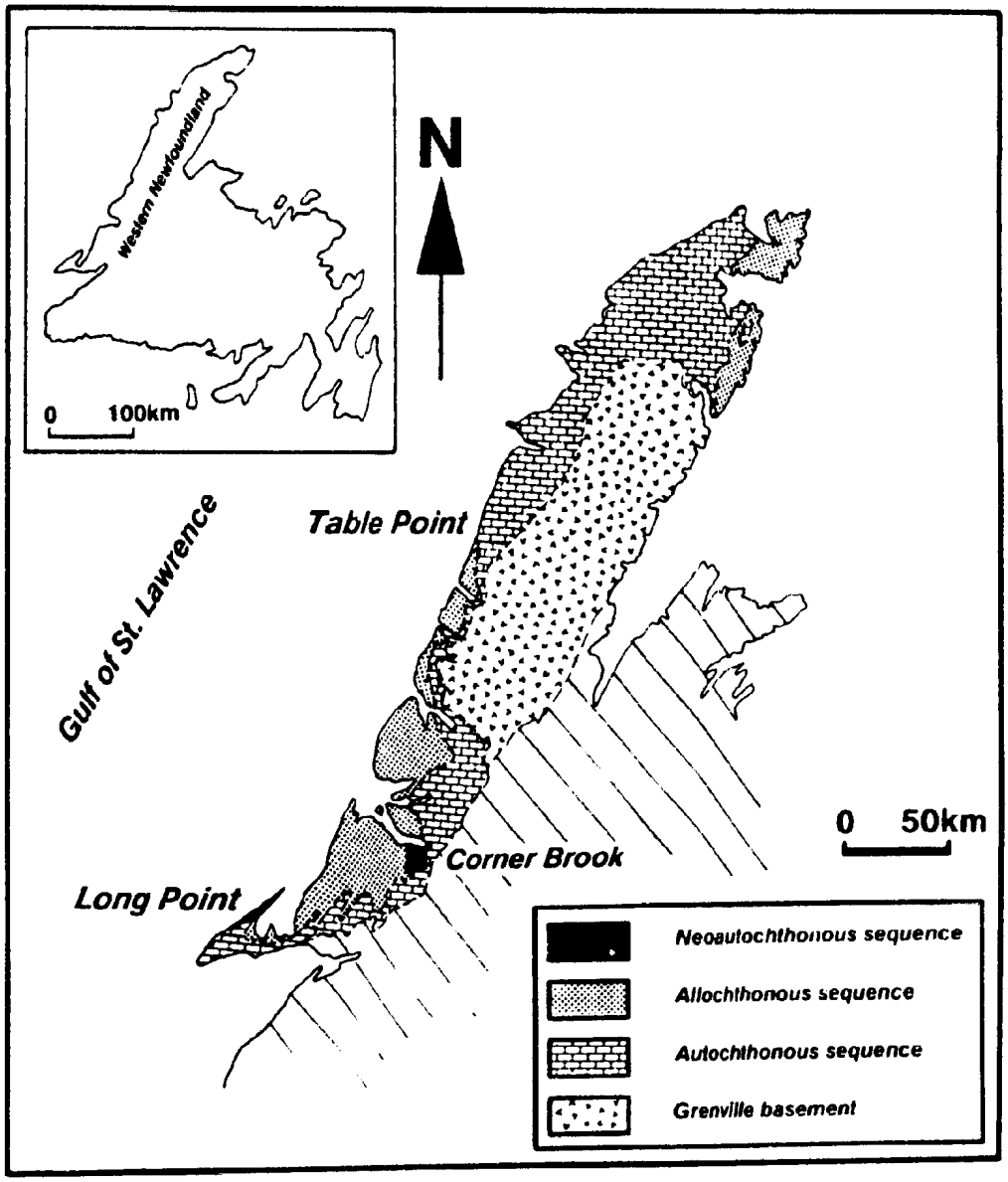


Fig. 3. Geological sketch map of the Humber Zone, western Newfoundland, (after James and Stevens 1986).

TABLE HEAD GROUP

Geological setting.- Autochthonous carbonates of the early Middle Ordovician Table Head Group (Fig. 4) are exposed at various points along the coast of western Newfoundland, from the Port au Port Peninsula in the south to Hare Bay in the north. Table Head Group carbonates were deposited along the western margin of a Taconian foreland basin and record the break-up and foundering of the long-lived Laurentian carbonate platform (Stenzel *et al.* 1990). Unlike older shelf carbonates that are arranged in a simple layer-cake fashion, the tectonically influenced Table Head Group is characterised by rapid facies changes that produced a mosaic of lithologic units which vary in both thickness and lateral continuity (Stenzel *et al.* 1990). The complex history of carbonate platform collapse and foreland basin development that is recorded in the group has been documented by Stenzel *et al.* (1990) and can be summarised as follows: (a) fragmentation, uplift and erosion of the platform and subsequent deposition of muddy limestones of the Table Point Formation, (b) break-up and sudden collapse of the platform, and deposition of deep-water, slope carbonates (Table Cove Formation), basinal black shales (Black Cove Formation) or conglomerates (Cape Cormorant Formation), and (c) burial by flysch (Goose Tickle Group).

Lithostratigraphy.- Stenzel *et al.* (1990) have recently revised the lithostratigraphy of the Table Head Group. They divide the Table Head Group into three formations, the Table Point Formation, the Table Cove Formation and the Cape Cormorant Formation. The lower boundary of the Table Head Group is taken at the unconformity between limestones of the Table Point Formation and the underlying dolostones of the St. George Group. Because of regional variations in the distribution

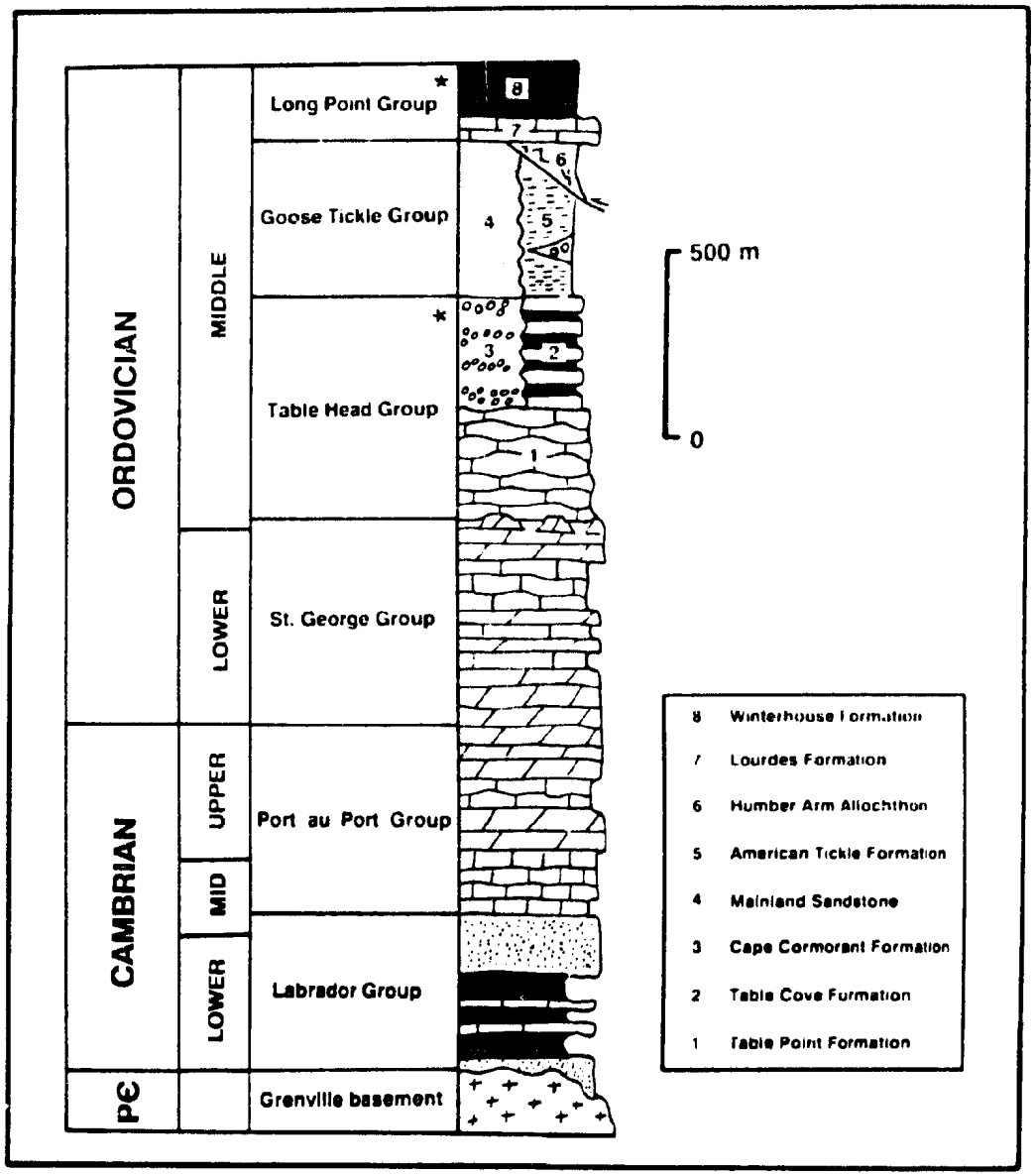


Fig. 4. Generalised stratigraphic section through the autochthonous carbonate succession, western Newfoundland, (after James and Stevens 1986 and Stenzel *et al.* 1990). Stratigraphic units marked with an asterix (⋆) were sampled.

of its three constituent formations, the upper boundary of the Table Head Group (marked by the first deposition of flysch-type clastics`, is locally taken at the top of the Table Point, Table Cove or Cape Cormorant formations (Stenzel *et al.* 1990).

The Table Point Formation is laterally continuous, but exhibits marked non-systematic variations in thickness. At its type section (Table Point) for example, the formation is about 25C m thick, while in the Port au Port area it can be as little as 40 m thick. The Tabie Point Formation consists of a series of thick-bedded or massive, grey, fossiliferous limestones that exhibit a stylo-nodular to pseudoconglomeratic fabric (Stenzel *et al.* 1990).

The Table Cove Formation is laterally impersistent and exhibits dramatic variations in thickness: at its type section (Table Cove) the formation is 95 m thick, while in other areas it is not developed. Where it is present, the Table Cove Formation overlies the Table Point Formation gradationally and consists of a series of thinly interbedded limestones and black calcareous shales, which are pervasively slump-folded.

The Cape Cormorant Formation overlies the Table Point Formation on the Port au Port Peninsula. At its type locality (Cape Cormorant) the formation is 200 m thick and consists of massive, carbonate lithoclast conglomerates, interbedded with calcarenites (Stenzel *et al.* 1990).

Depositional environments.- Table Head Group limestones were deposited in a series of progressively deepening environments that record the collapse of the carbonate platform (Klappa *et al.* 1980; James *et al.* 1988; Stenzel *et al.* 1990). Correlative equivalents to the Whiterockian (early Llanvirnian) Table Head Group are absent over most of the North American craton, and this period of time is represented by a major hiatus, which is recorded as a disconformity or paleokarst surface (Williams *et al.* 1987).

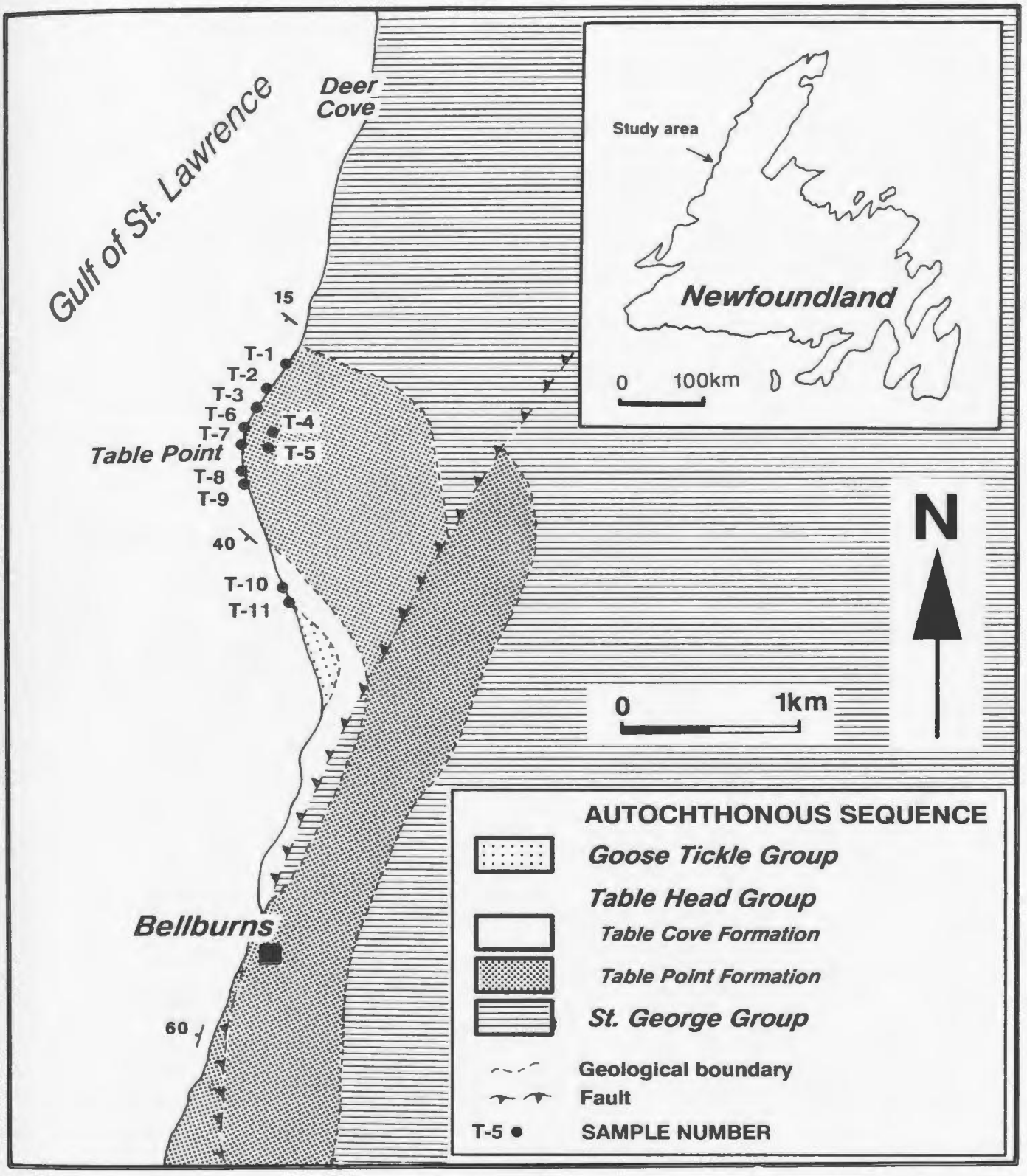


Fig. 5. Geological sketch map of the Table Point area, western Newfoundland, (after Knight 1985).

Despite regional variations in thickness, the vertical succession of lithofacies in the Table Point Formation is uniform throughout western Newfoundland and indicates an upward change from gradual subsidence to platformal shoaling (Stenzel *et al.* 1990). The succession consists of peritidal limestones and minor dolostones that are overlain by muddy, shallow subtidal limestones. Slumps, slides and intraformational conglomerates occur throughout the Table Point Formation and provide ample evidence of the tectonic instability associated with the platform foundering.

With further break-up and collapse of the platform, local tilting produced a gently dipping, carbonate ramp or slope on which the Table Cove Formation was deposited (Stenzel *et al.* 1990). The Table Cove Formation is a sequence of progressively deeper water, slope sediments that range from bioturbated, highly fossiliferous limestones at the base, to interbedded ribbon limestones and black shales at the top. The lower fossiliferous, burrowed limestones were deposited *in situ* on the upper slope, while the upper ribbon limestones are interpreted as storm-generated turbidites that accumulated in a deeper, distal-slope environment (Stenzel *et al.* 1990).

During the final phase of platform foundering, massive conglomerates of the Cape Cormorant Formation were shed from thrust-generated, submarine scarps into a deeper water, lower slope environment that was characterised by continuous clay sedimentation (Stenzel *et al.* 1990).

Age and correlation.- The graptolite, trilobite, brachiopod and conodont biostratigraphy of the Table Head Group has recently been summarised by Williams *et al.* (1987). They note that the Whiterockian (early Llanvirnian) Table Head Group entirely postdates the Cow Head Group. More details of the age of the Table Head Group, its equivalents in Nevada, and the Whiterock problem can be found in Cooper (1956), Whittington and Kindle (1963), Ross (1970), Ross and Ingham (1970), Fåhræus (1977), Stouge (1984) and Ross and James (1987).

Faunas.- The Table Point Formation contains a diverse assemblage of shelly fossils that includes leperditiid ostracodes, plani-spired and high-spired gastropods, orthid brachiopods, orthoconic and coiled cephalopods, illaenid and bathyurid trilobites and lithistid sponges (Klappa *et al.* 1980; Stenzel *et al.* 1990).

Limestones of the lower Table Cove Formation contain lingulids, asaphid and cheirurid trilobites as well as fragments of many of the same shelly fossils that occur in the Table Point Formation. The interbedded shales of the upper Table Cove Formation contain graptolites, fragments of shelly fossils and small inarticulate and articulate brachiopods (Stenzel *et al.* 1990).

Detailed accounts of the diverse faunas of the Table Head Group have been made by many authors. The following fossil groups have been recorded: *graptolites*, (Morris and Kay 1966; Finney and Skevington 1979; Williams *et al.* 1987); *trilobites*, (Whittington and Kindle 1963; Whittington 1965; Williams *et al.* 1987); *conodonts*, (Fåhræus 1970; Stouge 1984; Williams *et al.* 1987); *brachiopods*, (Cooper 1956; Pickerill *et al.* 1984a; Ross and James 1987); *cephalopods*, (Flower 1978); *sponges*, (Klappa and James 1980).

LONG POINT GROUP

Geological setting.- The Long Point Group outcrops along both sides of Long Point (Fig. 6), a prominent peninsula that forms the northwest coast of the Port au Port Peninsula. The mid-Middle to Upper Ordovician Long Point Group (Fig. 4) has traditionally been regarded as a cover sequence that unconformably overlies the Humber Arm Allochthon (Rodgers 1965; Brückner 1966; Kay 1969) and thus defines the maximum age of allochthon emplacement. In addition, the inferred stratigraphic continuity between the Long Point Group and the underlying Goose

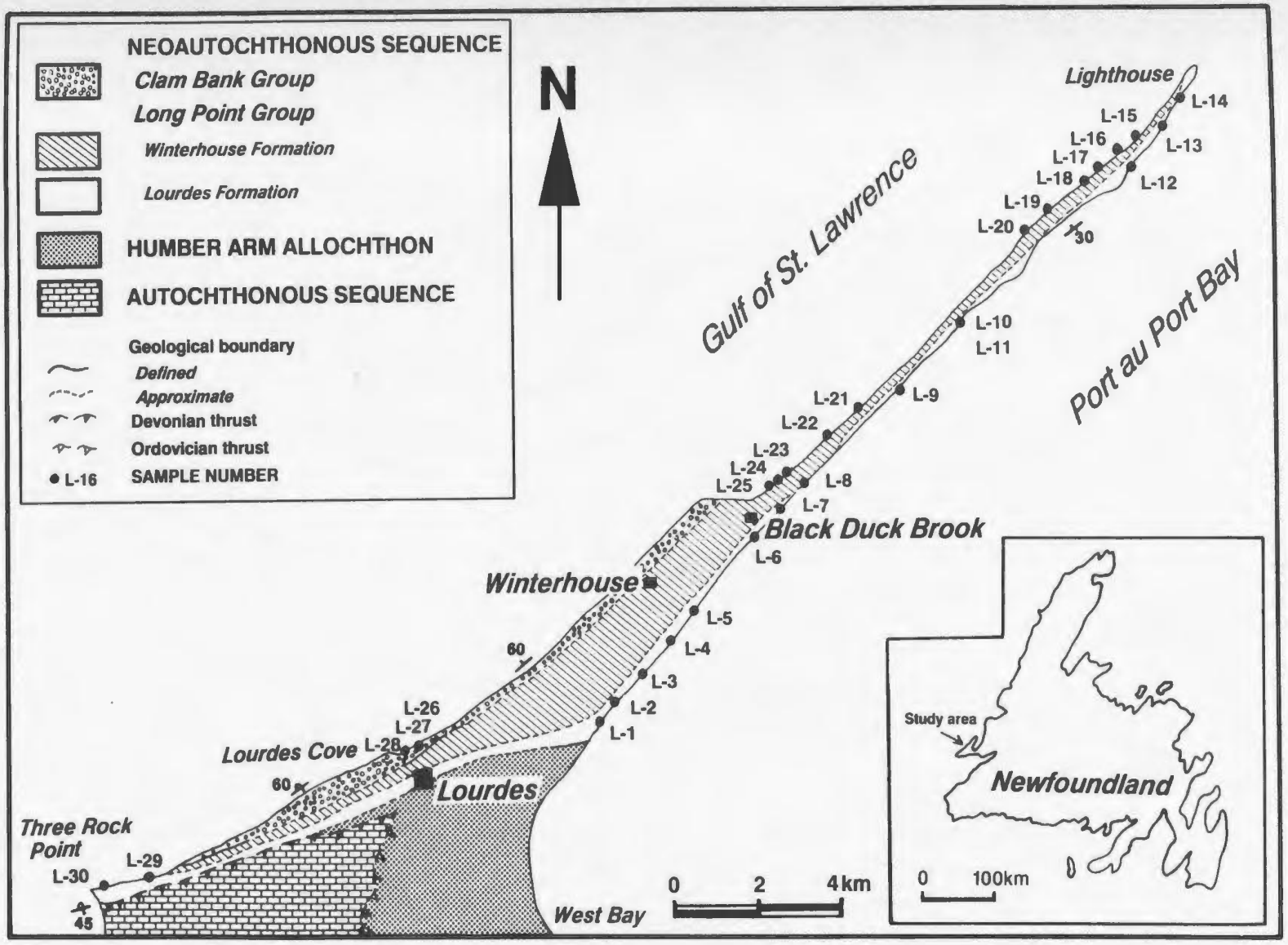


Fig. 6. Geological sketch map of the Long Point area, western Newfoundland (after Williams 1985)

Tickle Group has been interpreted as defining the western limit of allochthon transport in the Port au Port area (Stevens 1970; Schillereff and Williams 1979). Geological maps of the Long Point area have been constructed by Riley (1962), Corkin (1965), Rodgers (1965), Weerasinghe (1970), Shaikh (1971) and Williams (1985). Strata of the Long Point Group generally strike northeastward and young to the northwest, but are overturned in the vicinities of Lourdes and Three Rock Point, as a result of the Acadian Orogeny (Cawood and Williams 1988).

Lithostratigraphy.- The Long Point Group consists of the Lourdes Formation and the overlying Winterhouse Formation (Bergström *et al.* 1974). The contact between the two formations is abrupt but conformable. The general succession has been recorded by Riley (1962), Rodgers (1965), Kay (1969), Fåhræus (1973), Bergström *et al.* (1974), James and Stevens (1982) and Stait (1988). The upper boundary of the group is unexposed and has been interpreted as both a fault (Sullivan 1940; Riley 1962) and a disconformity (Rodgers 1965; Fåhræus 1973). The lower boundary of the group was originally considered to be a fault (Schuchert and Dunbar 1934). However, later workers (Rodgers 1965; Brückner 1966; Kay 1969) suggested that the Long Point Group was neoautocthonous and rested unconformably on the Humber Arm Allochthon. In the light of marine seismic data, Stockmal and Waldron (1990) have recently re-interpreted the contact between the Long Point Group and the Humber Arm Allochthon as an Acadian back-thrust.

The Lourdes Formation is about 80 m thick and has most commonly been divided into three members (Kay 1969; Bergström *et al.* 1974; Stait 1988), now known as the Shore Point, Black Duck and Beach Point members (Stait 1988). The Shore Point Member consists of 5 m of cross-bedded sandstone, which grades upward into 14 m of rubbly-weathering, sandy limestone with thin limestone interbeds. The overlying Black Duck Member consists of 6 m of shaly limestone that grades into 15 m of very

fossiliferous lime mudstones and grainstones with common small bryozoan (Cuffey 1977) or tabulate coral (Copeland and Bolton 1977) reefs. The reef unit is overlain by the Shore Point Member which consists of about 35 m of light grey, arenaceous limestone interbedded with blue calcareous shale.

The overlying Winterhouse Formation is a coarsening upward succession of thin-bedded calcareous siltstones, shales and sandstones which pass gradationally into red beds of the Clam Bank Group. The Winterhouse Formation is intermittently exposed along the west side of Long Point, and a 330 m section can be measured here. The contact between the Winterhouse Formation and the Clam Bank Group is not exposed on the coast northwest of Black Duck Brook, but can be seen in a stream section at the north end of Lourdes Cove (Schillereff and Williams 1979).

Depositional environments.- Little detailed sedimentology has been done on the Long Point Group. Fåhræus (1973) suggested that the Lourdes Formation was deposited in a barrier island setting, that was characterised by beachsands, mudflats, intertidal lagoons, a subtidal carbonate bank and fringing reef. More recently Stait (1988) interpreted the Lourdes Formation as three shallowing upwards carbonate sequences within a progressively deepening basin. The shaly bases of the Black Duck and Beach Point members have been interpreted (B. Stait, personal communication, 1988) as the result of deepening events that coincide with eustatic sea-level changes.

Fåhræus (1973) interpreted the depositional environment of the Winterhouse Formation as a prograding fluviomarine delta, because he discerned two clear upward trends in the formation. Firstly, a progressive increase in the clastic-carbonate ratio and secondly, a gradual transition into red alluvial sands.

Age and correlation.- There is now a general consensus that the age of the Lourdes Formation ranges from the Blackriverian to the Rocklandian (Fåhræus 1973;

Bergström *et al.* 1974; Dean 1979). The age of the Winterhouse Formation is less certain, conodonts (Fåhræus 1973) indicate that the formation ranges in age from the Kirkfieldian to the Shermanian, whereas graptolites suggest a Maysvillian age for the lower part of the formation (Bergström *et al.* 1974) and an older Edenian age for the top of the formation (O'Brien 1975; S.H. Williams, personal communication, 1987).

Faunas.- Collections and studies of fossils from the Long Point Group have largely been confined to the diverse faunas of the Lourdes Formation. Apart from the basal sandstone (5 m), the entire formation is fossiliferous, with the richest fossil assemblages being found in the upper 15 m of the Black Duck Member and the lower 7 m of the Beach Point Member. The following fossil groups have been recorded: *orthid and strophomenid brachiopods*, (Cooper *in* Riley 1962; Bergström *et al.* 1974); *phacopid, asaphid and illaenid trilobites*, (Dean 1979); *orthocone cephalopods*, (Bergström *et al.* 1974; Stait 1988); *bivalves and gastropods*, (Bergström *et al.* 1974); *pelmatozooan stems and fragments*, (Bergström *et al.* 1974; James and Stevens 1982); *tabulate and rugose corals*, (Bolton 1965a; Fritz 1966; Bergström *et al.* 1974; Copeland and Bolton 1977); *colonial bryozoa*, (Fritz 1966; Bergström *et al.* 1974; Cuffey 1977); *sponges and stromatoporoids*, (Copeland and Bolton 1977; James and Stevens 1982); *conodonts*, (Fåhræus 1973, 1973a; Bergström *et al.* 1974).

The Winterhouse Formation is very fossiliferous in places but its faunas have received less attention than those of the Lourdes Formation and only the following fossil groups have been recorded: *trilobites*, (Whittington *in* Rodgers 1965; Dean 1979); *graptolites*, (Bergström *et al.* 1974); *brachiopods*, (Fåhræus 1973); *conodonts*, (Fåhræus 1973, 1973a; Bergström *et al.* 1974).

Further details of Long Point Group fossils can be found in the early works of Murray and Howley (1881) and Schuchert and Dunbar (1934), together with the

unpublished theses and reports of Sullivan (1940), Corkin (1965), Weerasinghe (1970), Shaikh (1971) and O'Brien (1975).

ANTICOSTI ISLAND

INTRODUCTION

Location, access and physiography.- Anticosti Island (Fig. 7) lies in the Gulf of St. Lawrence and is about 200 km long, by up to 50 km wide. The only permanent settlement on the island is Port Menier, which can be reached by scheduled ferry from Rimouski or by air from Sept Isles. The island is served by a network of gravel roads that were constructed by the pulp and paper companies that logged Anticosti between 1926 and 1973 (MacKay 1979). In 1974, the island was sold to the Province of Québec and became a deer hunting and salmon fishing reserve. Anticosti Island is generally low-lying and is covered by dense stands of spruce and balsam. The geology of the island is well exposed in coastal cliffs; inland exposure is limited to river valleys and road-cuts.

REGIONAL GEOLOGY

Previous studies.- Investigation of Anticosti's geology was pioneered by Richardson (1857) and Billings (1857). More than fifty years elapsed before work on the

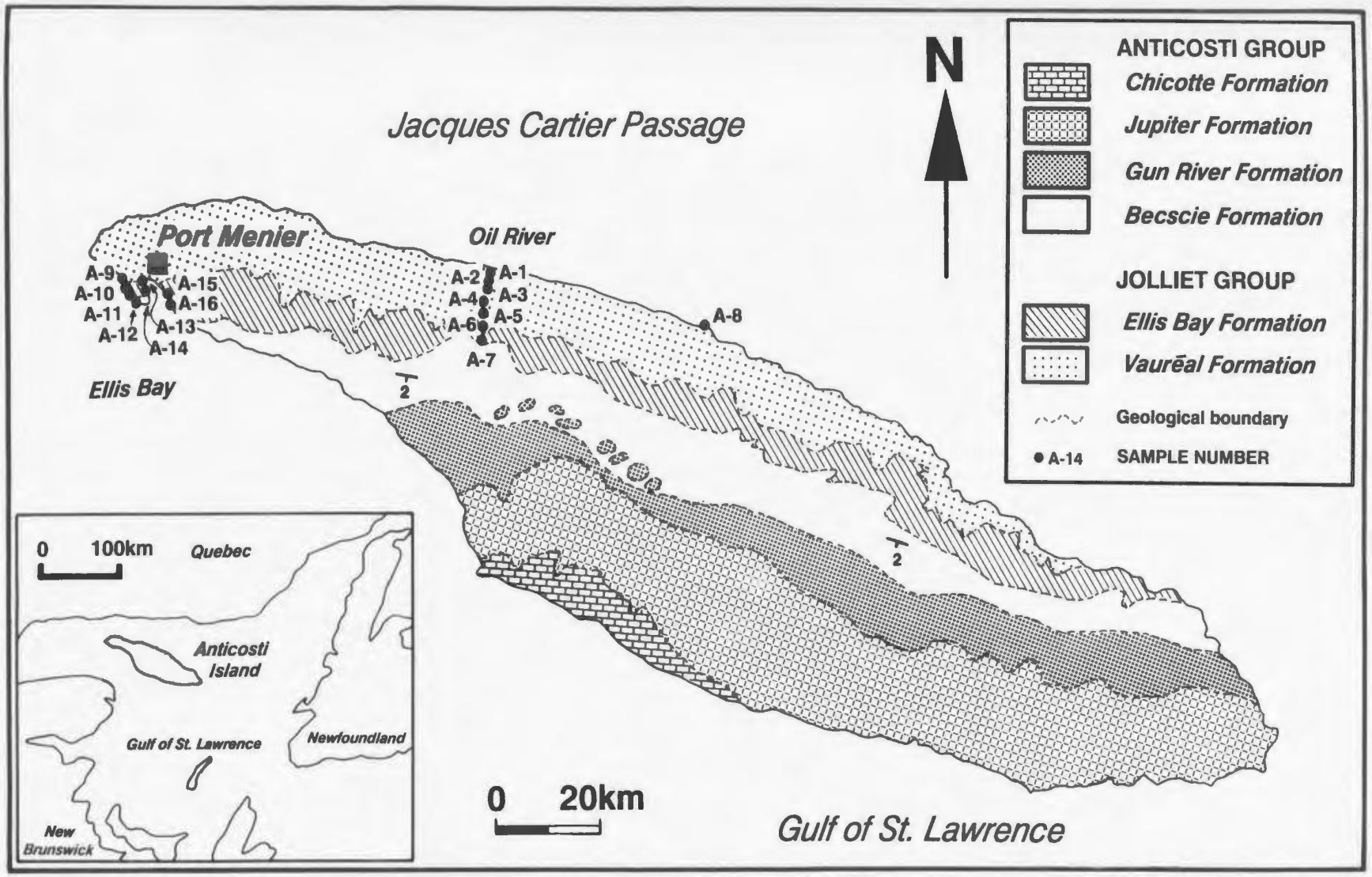


Fig. 7. Geological sketch map of Anticosti Island, (after Petryk 1981c and Barnes 1988).

stratigraphy of Anticosti Island was resumed by Schuchert and Twenhofel (1910) and subsequently by Twenhofel (1914, 1921, 1926, 1928). In 1957, the Geological Survey of Canada began a survey and mapping project aimed at improving knowledge of the Island's stratigraphy. Many previously undescribed road-cuts and river sections were examined during the course of this work which resulted in Bolton's publications of 1961, 1965, 1970 and 1972. Copeland (1970, 1973, 1974a) described the ostracode faunas from many of these new sections. In 1976, the Québec Ministère de l'Energie et des Ressources initiated a programme to assess the geology of Anticosti, this work resulted in Petryk's reports of 1976, 1979, 1981a, 1981b and 1981d and the most up-to-date geological maps of the island (Petryk 1981c). Much of the recent work on the geology of Anticosti Island (Lespérance 1981, 1981a, 1985 and Barnes 1988, 1989) has been associated with consideration of sections as possible stratotypes for the Ordovician-Silurian systemic boundary.

Geological evolution.- The Lower to Middle Ordovician was a period of stable platformal carbonate sedimentation in the Anticosti Basin. During the Taconic Orogeny the area was converted into a foreland basin, and the deep-water black shales of the subsurface Macasty Formation, were deposited. Deposition of the overlying Vauréal and Ellis Bay formations marked the final infilling of this foreland basin and a return to a pattern of stable, carbonate platform sedimentation that persisted throughout the Lower Silurian (Barnes 1988).

Regional geological setting.- Anticosti Island exposes the upper part of the Lower Ordovician to Lower Silurian Anticosti Basin succession (Fig. 8). The lower part of this platformal sequence underlies the Jaques Cartier Passage and is discontinuously exposed in a narrow strip along the north shore of the Gulf and in the Mingan Islands (Nowlan and Barnes 1981). The 1.1 km thick, shaly carbonate sequence that outcrops

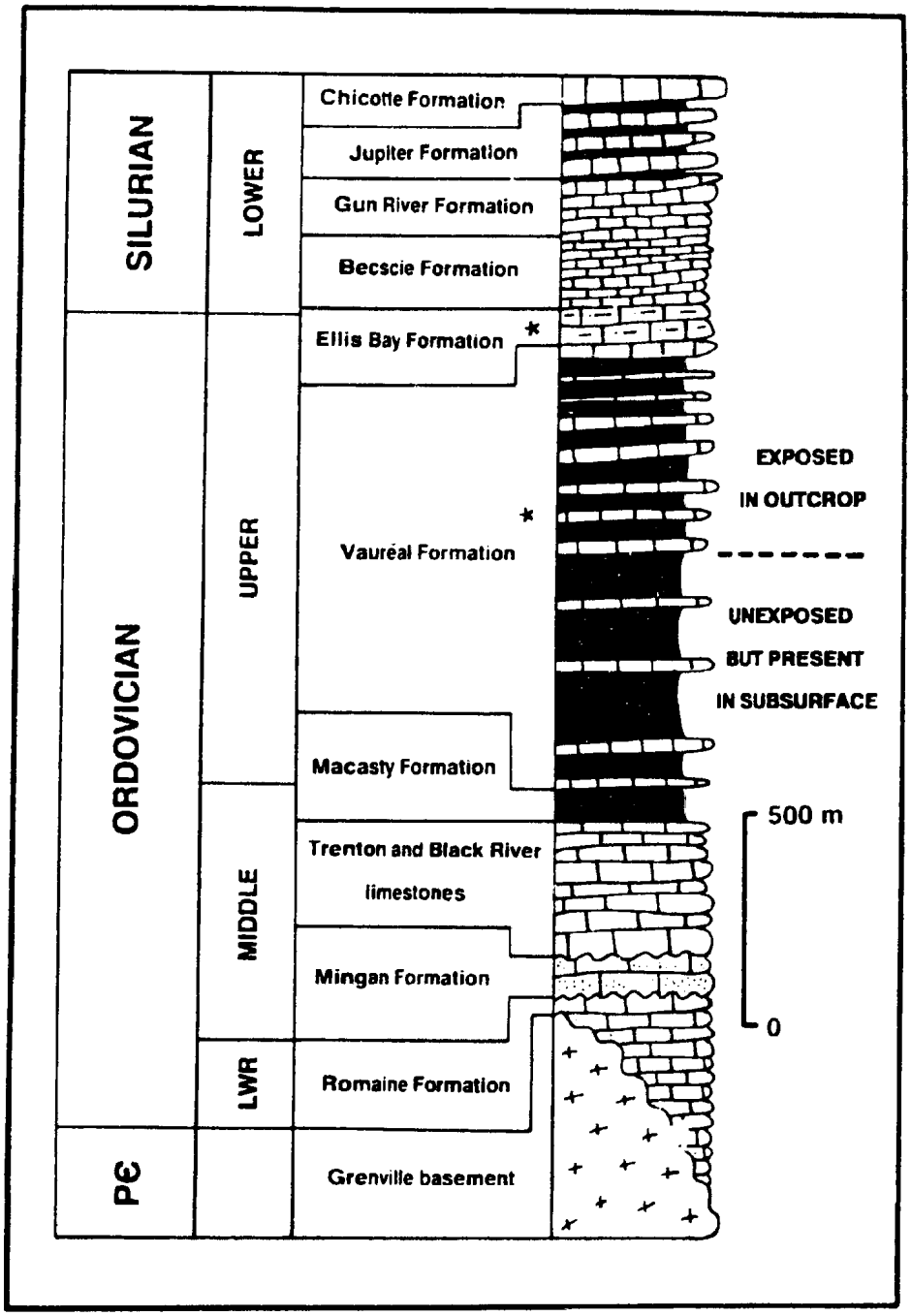


Fig. 8. Generalised stratigraphic section through the Anticosti Basin succession, (after Roliff 1968, Petryk 1981b and Barnes *et al.* 1981). Stratigraphic units marked with an asterix (*) were sampled.

on Anticosti Island is very fossiliferous and ranges in age from the Upper Ordovician to the Lower Silurian (Barnes 1988). The sedimentary succession on Anticosti Island contains virtually the entire spectrum of shallow marine, carbonate facies and is a continuous conformable sequence, in which lithofacies changes are generally gradational (Petryk 1981b). Anticosti's strata are undeformed and dip gently at less than two degrees to the southwest.

SUBSURFACE GEOLOGY.- The Anticosti Basin succession is at least 2.5 km thick; of this only about 1.1 km are exposed on Anticosti Island (Fig. 8). The rock units underlying Anticosti Island are not well known having only been seen in holes drilled for oil and gas (Roliff 1968; Petryk 1981a; SOQUIP 1987). Subsurface pre-Macasty Formation rocks have largely been dated (Barnes *et al.* 1981) by comparison with similar rocks that outcrop on the Mingan Islands.

SURFACE GEOLOGY.- The strata exposed on Anticosti Island have been divided into the Jolliet Group (Petryk 1979) and the overlying Anticosti Group (Billings 1857; Twenhofel 1928; Petryk 1979). The Jolliet Group is a cyclical sequence of thin limestones and marly shales (Petryk 1981b), which has been divided into the Vauréal Formation and the overlying Ellis Bay Formation. The Anticosti Group is a sequence of interbedded limestones and shales which are less argillaceous (Petryk 1981b), and more lithologically variable (Bolton 1972), than the underlying Jolliet Group. The early to late Llandovery (Barnes 1988) Anticosti Group is divided into four conformable formations, which are in ascending order the Becscie, Gun River, Jupiter and Chicotte formations.

Lithostratigraphy.- Richardson (1857), Schuchert and Twenhofel (1910), Twenhofel (1928), Bolton (1972) and Petryk (1981b, 1981c, 1981d) have all attempted stratigraphic subdivision of Anticosti's strata. Historically, the Anticosti succession has been divided stratigraphically on the basis of both lithological character and faunal

content. Some of Twenhofel's (1921, 1928) formations are groups of biozones, with formational boundaries drawn at horizons where specific taxa either appear or disappear. More recent work (Bolton 1972; Petryk 1981b) has emphasised the importance of recognising formations which are mappable, lithostratigraphic divisions. Despite lithostratigraphic revisions, differences between Anticosti's formations are subtle and formational boundaries can only be recognised in the field by slight variations in lithofacies. Some formational boundaries are stable and widely accepted (e.g., the Vauréal-Ellis Bay boundary), while others are unsettled (e.g., the Ellis Bay-Becscie boundary) with different authors (Bolton 1972; Petryk 1981b) advocating different levels for their boundaries. This author follows Petryk's (1981b) formational boundaries and thicknesses.

The general succession seen on Anticosti Island has been described by Twenhofel (1928), Bolton (1972) and Petryk (1981b, 1981c, 1981d). Unfortunately, detailed logs exist for only a few sections and with the exception of papers by Copper and his co-workers (e.g., Cocks and Copper 1981; Long and Copper 1987, 1987a; Copper 1989; Copper and Long 1989), little detailed sedimentology has been done.

Study areas on Anticosti Island.- Samples of ostracodes were collected from the Vauréal and Ellis Bay formations at Oil River and Ellis Bay (Fig. 7).

JOLLIET GROUP

Vauréal Formation.- Only the upper 460 m of the 1020 m thick Vauréal Formation is exposed on Anticosti Island. The Vauréal Formation is a sequence of thin-bedded, argillaceous limestones and grey calcareous shales, in which the shale content decreases up section. On the basis of its shelly fossils, the formation has generally

been considered to be of Richmondian age. However, graptolites (Riva 1969; Riva and Petryk 1981; Riva 1988) and conodonts (Nowlan and Barnes 1981) indicate that the upper part of the formation may be of Gamachian age.

Ellis Bay Formation.- Conformably overlying the Vauréal Formation is the much thinner Ellis Bay Formation (about 75 m thick) which consists of a series of discrete, rhythmically alternating units of thin-bedded, shaly limestones interbedded with blue grey shales (members 1, 3, 5), and thinly bedded limestones (members 2, 4, 6). The uppermost Member 7 consists of small bioherms developed on a widespread oncolitic platform bed (Barnes 1988). The Ellis Bay Formation is generally fossiliferous, and the more argillaceous members (1, 3, 5), contain a particularly diverse, abundant and well-preserved shelly fauna. Twenhofel (1928) was the first to recognise that the formation contains a latest Ordovician, post-Richmondian fauna which lacks North American correlative equivalents. He termed this post-Richmondian but pre-Llandoverian time interval the Gamachian. Later workers considered the Ellis Bay Formation to be of early Llandoverian (Ayrton *et al.* 1969; Berry and Boucot 1970) or Richmondian (Bolton 1972) age. After investigating the latest Ordovician conodont faunas of the formation, McCracken and Barnes (1981, 1981a) proposed the re-introduction of the Gamachian as a valid North American regional stage.

Further information on the stratigraphy and paleontology of the Vauréal and Ellis Bay formations can be found in the guidebooks to the Ordovician-Silurian Boundary Working Group's 1981 field meeting on Anticosti Island (Lespérance 1981, 1981a).

ST. LAWRENCE LOWLANDS

INTRODUCTION

Location, access and physiography.- The St. Lawrence Lowlands (Fig. 9) is a geographic term that refers to the low-lying areas on either side of the St. Lawrence River. The Lowlands lie between the Laurentian highlands to the northwest and the Appalachian uplands to the southeast.

The St. Lawrence Lowlands is a rich agricultural area, with a long history of settlement and development. The main urban centres are Montréal, Québec City and Trois-Rivières, all of which have developed at bridging points over the St. Lawrence River. Most areas of the Lowlands are served by a dense network of all-weather and gravel roads.

Geological exposure in the Lowlands is poor and natural exposure is generally limited to the banks of the St. Lawrence River and its major tributaries. Man made exposures such as road-cuts, quarries (both abandoned and working) and exploratory boreholes provide much invaluable geological information.

REGIONAL GEOLOGY

Previous studies.- The first systematic geological investigations of the Lowlands were undertaken by Logan, Richardson and Billings, and are summarised in Sir William Logan's classic book, the *Geology of Canada* (Logan 1863). Little more was done

until the Survey published Ells' revised maps of the St. Lawrence Lowlands and Eastern Townships (Ells 1887, 1889, 1896, 1900). Other important early contributions on the Ordovician stratigraphy of the Lowlands, were made by Raymond (1913, 1914) and Foerste (1916, 1924). Between the 1930's and 1970's, several hundred wells were drilled for oil and gas. Logs of these wells are included in reports by Parks (1930, 1931), Belyea (1952), Clark (1956) Roliff (1967), Globensky (1972) and Williams (1973) are invaluable sources of geological information in an area which has little natural exposure.

In 1924, T.H. Clark of McGill University published his first paper on the geology of the St. Lawrence Lowlands. Clark's remarkable record of continuous publication (e.g., Clark 1934, 1944, 1952, 1964a, 1972a, 1977 etc.) over the next fifty years has made a lasting contribution. Several of Clark's students also went on to publish on the Ordovician stratigraphy of the Lowlands (e.g., Okulitch 1936, 1939; Hofmann 1963, 1972, 1989). Between the 1950's and 1970's Clark, and later Clark and Globensky mapped virtually the entire Lowlands as a series of discrete mapping quadrants; their maps and explanatory notes appeared as a series of Québec Provincial Government reports (e.g., Clark 1964, 1972; Clark and Globensky 1973, 1975, 1976a, 1977). Globensky continued to map (e.g., Globensky 1978, 1981, 1982) and has recently (1987) published the most up-to-date geological map and report on the Lowlands.

Although the paleontology of the Ordovician strata exposed in the Lowlands has long been neglected, the past twenty years has seen detailed description of the graptolites (Riva 1969, 1972, 1974; Walters 1977, 1979) and conodonts (Globensky and Jauffred 1971, 1971a; Mehrtens 1979). The shelly macrofaunas of the Lowlands are largely undescribed, and are only known from the faunal lists that accompany map reports.

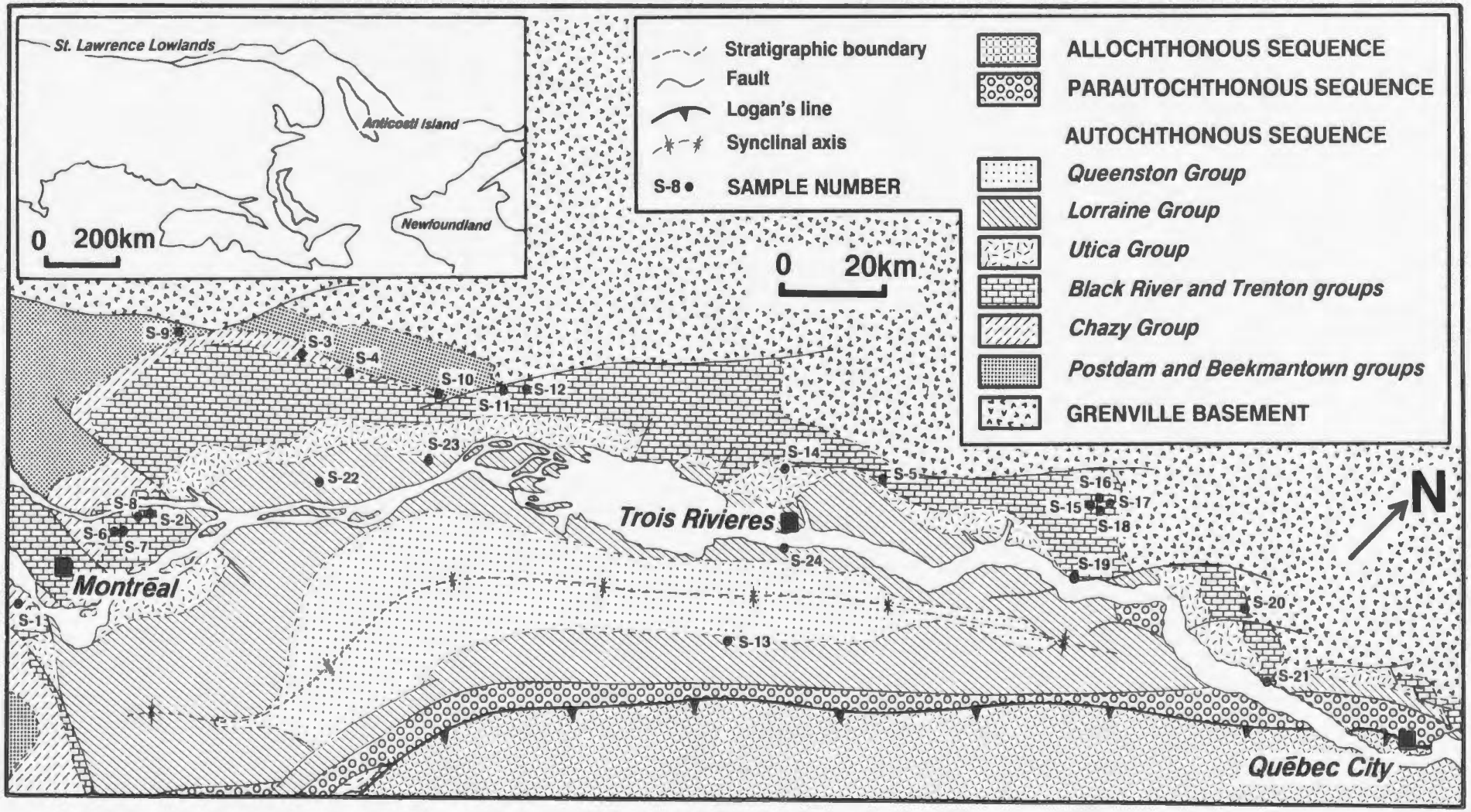


Fig. 9. Geological sketch map of the St. Lawrence Lowlands of Québec, (after Globensky 1987).

In 1979, a 150 km long seismic line was shot across the St. Lawrence Lowlands southeastward into the Québec Appalachians. St. Julien *et al.* (1983) used this seismic data to construct a deep structural profile illustrating the nature of the transition from autochthonous to allochthonous rocks in the subsurface of southern Québec.

The recent theses by Mehrtens (1979) and Parker (1986) made the first real efforts to synthesise observations on the Ordovician sediments of the Lowlands into coherent depositional models. Harland and Pickerill's (1982) and Mehrtens' (1988) reviews of Ordovician sedimentation in the St. Lawrence Lowlands provide good up-to-date summaries of the geological development of the region.

Stratigraphic terminology.- As in many areas with a long history of geological investigation, the stratigraphic nomenclature applied to the Cambro-Ordovician succession in the St. Lawrence Lowlands is out-of-date and in need of revision. Many of the *ad hoc* stratigraphic terms in use do not conform to the *North American Stratigraphic Code*. For example the term "Trenton" has historically been used in the Lowlands with a lithostratigraphic connotation, implying some sort of lithostratigraphic relationship with limestone strata of the Trenton type section. This correlation is never discussed in the literature and use of the term "Trenton" invariably implies a Middle Ordovician age (Desbiens and Lespérance 1989).

In addition to the inherent confusion caused by use of the term "Trenton", there are a number of other stratigraphic problems, such as: (a) application of synonymous names to similar rock units, e.g., basal Trenton Group strata are assigned to five different formations between Montréal and Québec City (Harland and Pickerill 1982), (b) wide fluctuations in the scale of stratigraphic units, e.g., the Saint Alban Formation is 2 m thick (Harland and Pickerill 1982) while the Nicolet Formation is almost 2 km thick (Walters *et al.* 1982), and (c) faunal criteria being used to define

and recognise mapping units, e.g., Clark's (1972) division of the Montréal Formation into two members on the basis of its bryozoan content.

It is clear from this brief review that the stratigraphic terminology used to subdivide the Lowlands succession is inadequate and in need of revision. Since such a revision has not been attempted too date and is outside the scope of this study, the established stratigraphic terms are retained here.

Regional geological setting.- Cambro-Ordovician platformal sediments of the St. Lawrence Lowlands lie between the Precambrian Laurentian highlands in the northwest and deformed rocks of the Appalachian Orogen to the southeast (Fig. 9). A major northeast trending *en echelon* fault system defines the northwestern boundary of the Lowlands shelf succession with the Canadian Shield. The southeastern limit of the Lowlands succession is a complex zone of deformed sedimentary rocks that marks the western limit of west-directed Appalachian thrust sheets (Hofmann 1989).

The Cambro-Ordovician succession (Fig. 10) which underlies the St. Lawrence Lowlands is up to 2.6 km thick and directly overlies an irregular crystalline Grenvillian basement. This succession has been folded into a broad, northeast trending, asymmetric syncline, the eastern limit of which is obscured by Appalachian overthrusting. Deposition of the Lowland's platformal sequence was essentially continuous and the contacts between stratigraphic units are gradational. Facies patterns in the Cambro-Ordovician succession are complex and largely undocumented.

During the Cretaceous, the platformal succession was intruded by several alkaline complexes which now form the Monteregion hills. The effects of Quaternary glaciation can be seen in the unconsolidated sediments that occur throughout the Lowlands (Gadd 1971).

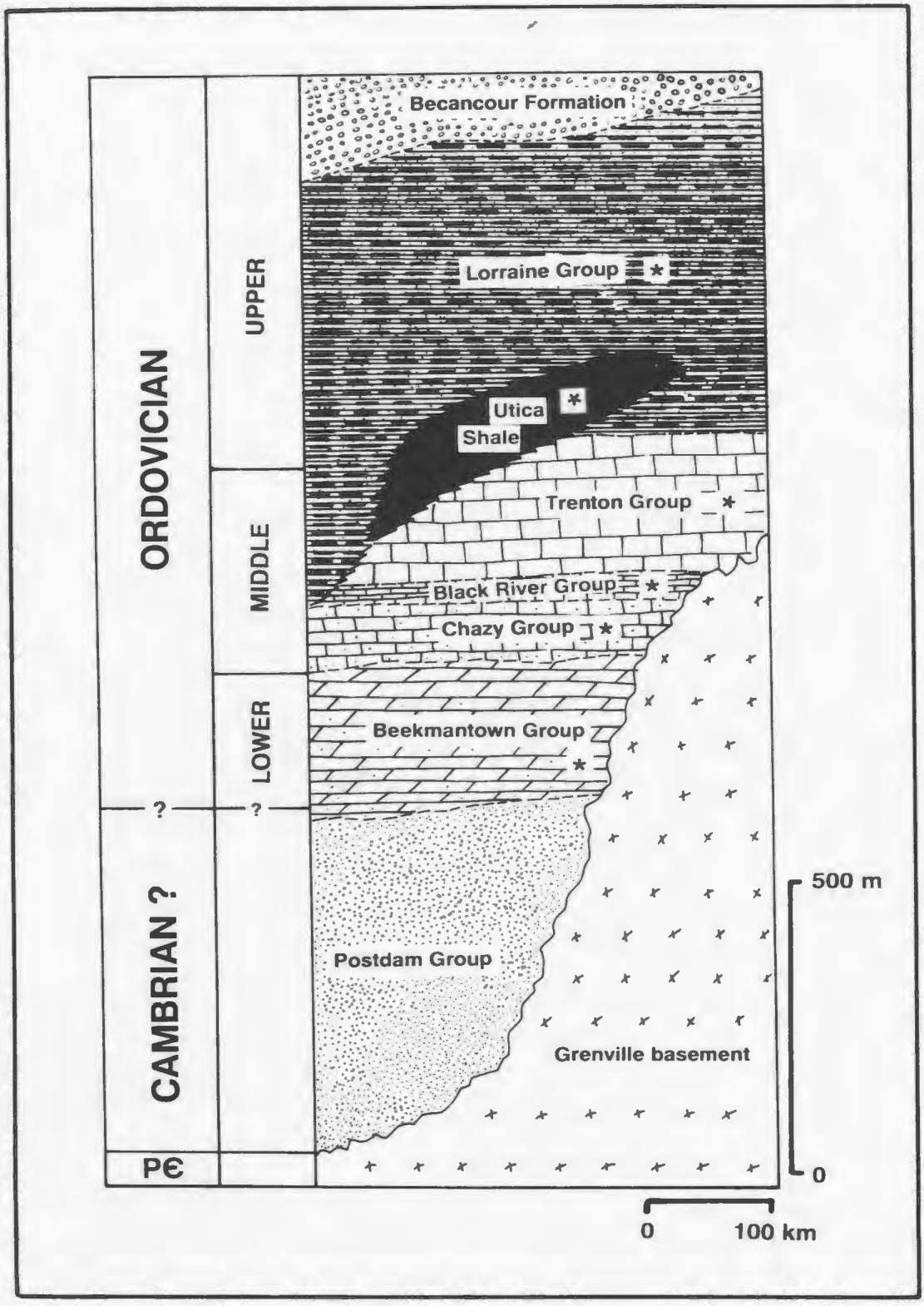


Fig. 10. Generalised stratigraphic section through the Cambro-Ordovician succession in the St. Lawrence Lowlands, (after Hofmann 1972, 1989 and Barnes *et al.* 1981). Stratigraphic units marked with an asterix (★) were sampled.

Geological evolution.- The platformal and miogeoclinal section preserved in the Lowlands records the latest Precambrian to Ordovician development and destruction of the passive margin of Laurentia.

Following late Precambrian rifting of the Laurentian craton and the opening of Iapetus, craton-derived rift sediments (Postdam Group) were deposited along the passive margin. By the end of the Cambrian, continued Iapetan divergence led to the development of an extensive platform, on which carbonates of the Lower Ordovician Beekmantown and early Middle Ordovician Chazy groups accumulated.

By the early Middle Ordovician closure of the Iapetus Ocean was well underway and the Laurentian margin had changed from a divergent passive margin to an active convergent margin. Because the timing of collision along this margin is strongly diachronous (Stockmal *et al.* 1987), Taconian orogenesis occurred at different times in different places. Development of the Taconian Orogen provided a new source of detritus (to the southeast) and depressed the lithosphere to form a northeastly trending foreland basin (Quinlan and Beaumont 1984) known as the St. Lawrence Trough. While carbonate sedimentation (Trenton Group) continued along the craton margin, deep-water black shales (Utica Group) and flysch from the rising Orogen filled the trough. As the Orogen progressed, the St. Lawrence Trough migrated westward and syn-orogenic sediments covered the carbonate platform. During the Late Ordovician, orogeny was intense and large volumes of Taconic detritus were transported across the Trough and onto the craton by a series of deltas (Lorraine Group) and rivers (Queenston Group).

Study areas in the St. Lawrence Lowlands.- The ostracodes investigated from the St. Lawrence Lowlands are from two sources: (a) samples collected and prepared by the author, and (b) ostracode collections prepared by Carter (1957) for his Ph.D thesis, and now known as the Carter Collection, (see Chapter 6 for further details).

Although ostracodes can be found in most parts of the Ordovician succession in the Lowlands, the faunas of the Trenton Group are the most diverse and abundant, and have been studied in the most detail.

GEOLOGICAL SUCCESSION

Outlined below are brief descriptions (with thicknesses in parentheses) of the main lithostratigraphic units in the Lowlands.

Postdam Group (0-600 m).- Unconformably overlying the Grenville Basement are arenaceous sediments of the latest Precambrian to Cambrian Postdam Group. The Postdam Group consists of alluvial deposits of the Covey Hill Formation which are overlain by shallow subtidal, shelf sediments of the Chateauguay Formation (Hofmann 1989). This change from terrestrial to marine sedimentation is a response to the transgression of the Sauk Sea over the Cambrian craton.

Beekmantown Group (about 250 m).- Deposition of the Lower Ordovician Beekmantown Group marked the onset of a long period of carbonate sedimentation in the Lowlands. The Beekmantown Group has been divided into two laterally equivalent formations, the Beauharnois Formation in the west and the Beldens Formation in the east (Hofmann 1989). Both formations are varied sequences of dolostones and dolomitic shales with thin interbeds of shelly limestone, sandstone and evaporites. Beauharnois dolostones include stromatolites, evaporites and mudcracks, suggesting restricted lagoonal, intertidal and supratidal deposition (Bernstein 1989; Hofmann 1989). The Beekmantown Group is part of the widespread sequence of

Lower Ordovician carbonates that accumulated over much of the North American midcontinent during the final stages of the Sauk Transgression.

Chazy Group (about 100 m).- Disconformably overlying the Beekmantown Group is the early Middle Ordovician Chazy Group. In southern Québec, the Chazy Group comprises one formation, the Laval Formation. The Laval Formation consists of a laterally variable, basal sandstone overlain by a sequence of thinly interbedded, muddy skeletal limestones, dolostones and dark shales. The formation contains a varied fossil fauna of corals, bryozoa, brachiopods and trilobites (Hofmann 1989). Basal sandstones of the Chazy Group were deposited in response to the transgression of the Tippecanoe Sea onto the cratonic surface (Frazier and Schwimmer 1987). As this epeiric sea deepened, shallow marine carbonates of the upper Chazy Group accumulated over much of the midcontinent.

Black River Group (about 20 m).- Although direct correlation with the type section of the Black River Group in New York State (Kay 1937) is not possible, the strata that occur between the Chazy and Trenton groups in southern Québec have historically been termed the Black River Group (Okulitch 1936). Between Montréal and Trois-Rivières the mid-Middle Ordovician Black River Group has been divided into three formations (Fig. 11), which are in ascending order the Pamelia, Lowville and Leray formations. The Pamelia Formation is a thin sequence of poorly fossiliferous dolostones, dolomitic shales and sandstones (Hofmann 1989). The Lowville Formation consists of interbedded pale argillaceous and oolitic limestones. The uppermost unit of the Black River Group is the Leray Formation, which consists of bioturbated, dark grey, micritic limestones with thin shale interbeds and partings (Harland and Pickerill 1982). Faunal abundance and diversity are generally poor, but some beds have rich pockets of shelly fossils. North of Trois-Rivières, the basal

clastic units which infill and overlap the Precambrian topography are known as the La Gabelle and Cap-a-l'Aigle formations, these formations are also assigned to the Black River Group (Clark and Globensky 1973; Mehrtens 1979). The mixed sandstones and carbonates of the Black River Group are interpreted as strandline sediments deposited in response to the continued encroachment of the Tippecanoe Sea onto the craton (Mehrtens 1988).

Trenton Group (about 250 m).- Carbonates of the late Middle to Upper Ordovician Trenton Group are the most widespread rocks in the St. Lawrence Lowlands. The Trenton Group is a mixed carbonate sequence, which has been subdivided into a number of geographically restricted stratigraphic units (Harland and Pickerill 1982). The Trenton succession (Fig. 11) is divided into three conformable stratigraphic packages: (a) the basal Trenton Group formations, (b) the widespread Deschambault Formation, and (c) interbedded limestones and shales of the upper Trenton Group.

Although Trenton Group carbonates are the most fossiliferous rocks in the Lowlands, the shelly faunas they yield are often long ranging and difficult to date or correlate (P.J. Lespérance, personal communication, 1989).

BASAL TRENTON GROUP SEDIMENTS.- In the Lowlands, the base of the Trenton Group consists of a thin (2-5 m) series of late Middle Ordovician argillaceous and shelly limestones. These limestones (Fig. 11) have traditionally been assigned to the following formations from southwest to northeast, the Mile End Formation (in and around Montréal), the Ouareau Formation (northern part of the Montréal-Joliette area), the Fontaine Formation (in the Trois-Rivières area east of the St. Maurice River), the St. Alban Formation (on the St. Anne River) and the Pont Rouge Formation (on the Jacques Cartier River). These formations are all lithologically similar and some authors (e.g., Harland and Pickerill 1982) regard them as lateral equivalents. Basal Trenton Group sediments are interpreted as restricted inner shelf

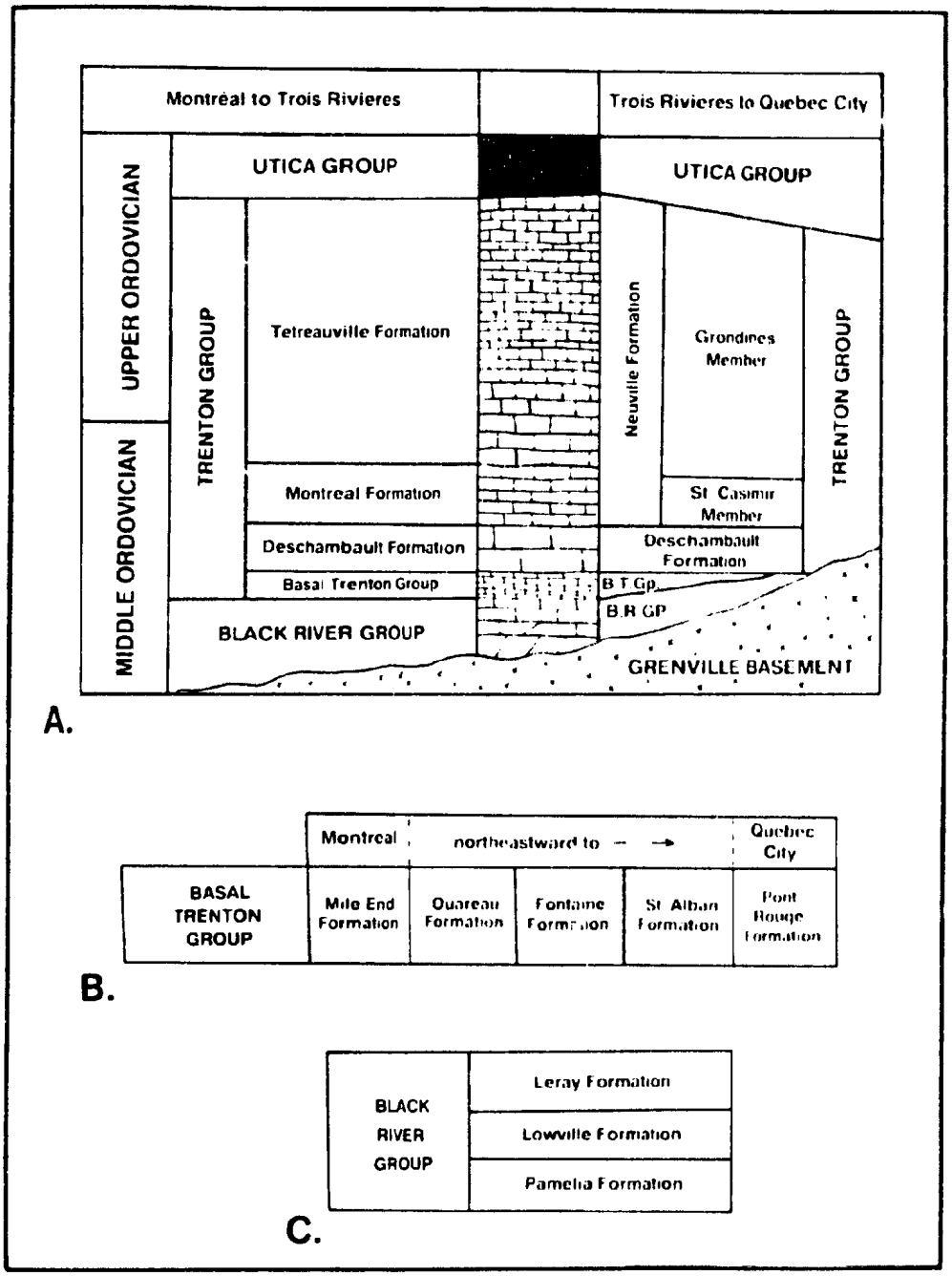


Fig. 11. (A) Stratigraphy of the Trenton Group in the St. Lawrence Lowlands, (after Mehrtens 1988). (B) Stratigraphy of the various basal Trenton Group formations in the Lowlands, (after Harland and Pickerill 1982). (C) Subdivisions of the Black River Group in the Lowlands.

deposits that accumulated craton-ward of the Deschambault carbonate build-ups (Mehrtens 1988).

DESCHAMBAULT FORMATION.- Throughout the St. Lawrence Lowlands, basal Trenton Group formations are gradationally overlain by the late Middle Ordovician Deschambault Formation (Mehrtens 1979). The Deschambault Formation (24-28 m) is typified by irregularly bedded, cross-stratified, skeletal limestones with numerous scours, lags and layers of shell hash. Most of the Deschambault Formation is very fossiliferous, containing a diverse fauna which is dominated by bryozoa and brachiopods. Conodonts (Globensky and Jauffred 1971; Mehrtens 1979) indicate that the lower part of the formation is of Kirkfieldian age.

The Deschambault Formation consists of a series of shallow-water, bryozoan dominated, carbonate build-ups that are surrounded by skeletal sands (Mehrtens 1988). These sediments were deposited on a shallow but progressively deepening carbonate ramp (Parker 1986a), that records the onset of shelf foundering in response to the Taconian Orogeny.

UPPER TRENTON GROUP.- Conformably overlying the Deschambault Formation in the Lowlands is a thick succession of interbedded limestones and shales which form the upper and major part of the Trenton Group. In the Montréal to Joliette area, the upper Trenton Group has been subdivided into the Montréal and Tétreauville formations (Fig. 11), while in the Trois-Rivières to Québec City area equivalent strata are known as the Neuville Formation (Fig. 11).

The Montréal Formation (110-140 m) consists of thin, irregularly bedded, argillaceous limestones interbedded with thin shale partings and skeletal layers (Harland and Pickerill 1982). The formation has a diverse fossil fauna which is dominated by brachiopods and bryozoans. On the basis of its bryozoa (Clark 1972) and conodonts (Mehrtens 1979), the Montréal Formation has been assigned a Kirkfieldian to Shermanian age.

The Tétreauville Formation (110-150 m) consists of an alternating sequence of thin-bedded argillaceous limestones, thin skeletal layers and dark shales (Harland and Pickerill 1982). In the upper parts of the formation this regular alternation of limestones and shales is occasionally replaced by a series of rubbly or nodular limestones known as the Terrebonne facies (Clark 1972). Although the Tétreauville Formation is not very fossiliferous, conodonts from the base of the formation are of Shermanian age (Mehrtens 1979) and graptolites from the upper part of the formation are of early Edenian age (Riva 1969, 1972, 1974).

In the Trois-Rivières to Québec City area, the Deschambault Formation is conformably overlain by the Neuville Formation (140-180 m), which has been subdivided into the lower Saint Casimir Member (40-60 m) and the upper Grondines Member (100-120 m). The Saint Casimir Member consists of a fossiliferous sequence of variable limestones interbedded with thin shale partings and layers of skeletal hash (Harland and Pickerill 1982). The overlying Grondines Member is very similar, but is generally finer grained with more shale interbeds and a sparser fauna. The age of the Neuville Formation is well constrained by conodonts (Globensky and Jauffred 1971, 1971a; Mehrtens 1979) and graptolites (Riva 1969, 1972, 1974; Riva *et al.* 1977) as ranging from the Shermanian to the Edenian.

Upper Trenton Group sediments accumulated on the outer portion of a gradually subsiding carbonate ramp (Mehrtens 1984, 1988). The amount of slump-folding, interbedded shales and bioclastic turbidites increases up section (Mehrtens 1988), reflecting basin deepening prior to platform foundering.

Utica Group (100-800 m).- In the Lowlands, the Trenton Group carbonates become progressively more argillaceous up section; when dark fissile shales become the dominant rock type the strata are termed the Utica Group. Although this contact is locally gradational, on a regional scale the upper Trenton Group and lower Utica

Group are coeval, and the contact is diachronous (Belt *et al.* 1979; Hofmann 1989). Apart from graptolites, fossils are rare in the Utica Group. Riva's (1969, 1972, 1974) work on graptolites indicates that the age of the Utica Group ranges from the Shermanian to the Maysvillian. Despite being widespread and compositionally uniform, the Utica Group has been subdivided into numerous local stratigraphic units. The naming of these various units, like the Utica shale, Lachine shale and Lobiniere Formation has become confused, and is discussed in detail by Belt *et al.* (1979). Black shales of the Utica Group were deposited in a deep, rapidly subsiding basin that records the foundering and burial of the carbonate platform (Mehrtens 1988). Further basin-ward a clastic wedge of syn-orogenic flysch was being shed off the westwardly migrating Taconic front.

Lorraine Group.- The thick argillaceous sequence that conformably overlies the Utica Group is known as the Lorraine Group. Exposure of the Lorraine Group is limited to the north shore of the Lowlands, where the group has been subdivided into the Nicolet and Pontgrave formations.

Much confusion has arisen over the definition of the Nicolet Formation, primarily because the formation was originally divided into a number of faunal zones (Foerste 1916, 1924) which later became the basis for Clark's (1947) lithostratigraphic subdivisions. There is still no consensus on the stratigraphy of the Nicolet Formation (for further details see: Belt *et al.* 1979; Beaulieu *et al.* 1980; Walters *et al.* 1982; Brandt-Velbel 1985). Estimates of the thickness of the formation vary between 760 m (Belt *et al.* 1979) and almost 2 km (Walters *et al.* 1982). The formation consists of a sequence of thinly bedded, dark grey shales and siltstones with minor sandstone interbeds. Although benthic fossils are quite common (Bretsky and Bretsky 1975; Brandt Velbel 1985), graptolites (Walters *et al.* 1981) are the only fossils that currently yield a satisfactory biostratigraphic zonation of the formation. The ages

assigned to the Nicolet Formation vary from Blackriverian to Richmondian (Barnes *et al.* 1981), to post-Shermanian but pre-Edenian (Walters *et al.* 1982) and Maysvillian (Hofmann 1989).

Clark (1947) termed the calcareous strata overlying the Nicolet Formation, the Pontgrave Formation (55 m). Apart from a few thin limestones these strata are similar to those of the Nicolet Formation. The Pontgrave Formation has a large shelly fauna and has been assigned a Richmondian age (Barnes *et al.* 1981).

The Lorraine Group has been interpreted as an easterly derived, shallow-water deltaic sequence (Belt and Bussières 1981; Frazier and Schwimmer 1987). Upper Ordovician detrital sediments like the Lorraine Group are widespread in northeastern North America; the detritus they contain was shed westwardly from the rapidly rising Taconic Orogen.

Queenston Group (about 600 m).- In the Lowlands, the Queenston Group consists of one formation the Becancour Formation, which is a thick sequence of unfossiliferous reddish siltstones, shales and sandstones.

Terrestrial red beds of the Queenston Group were deposited in a complex series of alluvial environments (Hofmann 1989). The transition from deltaic (Lorraine Group) to alluvial (Queenston Group) sedimentation resulted from the filling of the St. Lawrence Trough by the continued influx of Taconic detritus (Hofmann 1989).

CHAPTER 3

OSTRACODE FAUNAS

INTRODUCTION

This chapter details the results of research on the Ordovician ostracode faunas of western Newfoundland, Anticosti Island and the St. Lawrence Lowlands. Complete descriptions of the species which make up these faunas are found in the taxonomic section of this thesis (Chapter 6). Because the faunas are poorly known, this study is primarily taxonomic, and no ostracode-based correlations are made between the study areas.

The chapter includes: (a) summary of the field and laboratory methods used (full details of these methods can be found in Chapter 6), (b) brief remarks on the organization and scope of the study, (c) introductory comments on the faunas, and (d) description and interpretation of the ostracode faunas of each of the three study areas.

Before commenting on specific aspects of the study, several general remarks should be made. Ostracodes are much rarer in western Newfoundland and the St. Lawrence Lowlands than had been anticipated from examination of the literature. Even where ostracodes are relatively abundant, as on Anticosti Island, a large quantity of residue needs to be picked to obtain a representative fauna.

METHODOLOGY

Sampling procedures.- The main criterion influencing sample selection is the type of ostracode preparation method to be used. Careful selection of field samples that can be readily processed is essential.

Preparation techniques.- There are three main methods used to prepare Ordovician ostracodes: (a) washing: ostracodes are released from soft rocks by boiling and wet-sieving, (b) vibra-tool preparation: ostracodes are physically excavated from rock surfaces with a vibra-tool, and (c) acid preparation: chemical differences between rocks and the ostracodes they contain can be exploited, allowing ostracodes to be released during sample break-down.

Each of these preparation techniques requires a specific type of sample for greatest success. Samples for washing must be soft and susceptible to break-down; shales, shaly interbeds or weathered material give the best results. Samples for vibra-tool preparation must contain visible ostracodes. Silicified limestones are the best for hydrochloric acid preparation, while cherts and argillaceous limestones are the best for hydrofluoric acid preparation. The advantages and disadvantages of each of these preparation techniques are discussed below.

WASHING.- Washing is the technique most commonly used in studies of ostracodes. The main advantage of washed faunas is that they are relatively easy to prepare, while the main disadvantage is that they can only be obtained from rocks that readily break-down.

VIBRA-TOOL PREPARATION.- Vibra-tool preparation is the only technique that can be used to extract calcified ostracodes from indurate limestones. The main problems with this technique are: (a) visible ostracodes need to be found in the field, (b) it is extremely slow and time-consuming, (c) specimen yields are small, (d) larger and more ornamented specimens are likely to be preferentially selected, and (e) during preparation some specimens are more likely to break than others.

ACID PREPARATION.- The main advantage of acid preparation is that it is possible to obtain large numbers of well-preserved specimens. However sampling is blind, so that you cannot tell whether or not a rock will yield ostracodes until it is processed.

After preparation, the ostracode collections were stored on faunal slides or in plastic vials, assigned to various species and photographed.

ORGANIZATION AND SCOPE OF THE STUDY

Organization.- The remainder of this chapter is divided into two sections. First, a few introductory comments are made on: (a) the taxonomy of the faunas, (b) the mode of life of the ostracodes, (c) the reasons why ostracode-based biozones could not be recognised, and (d) the comparisons between the faunas of the study areas. Second, specific comments are made on the faunas of each of the three study areas, western Newfoundland, Anticosti Island and the St. Lawrence Lowlands. Ostracodes from each of these areas are discussed under the following five headings: (a) previous

studies, (b) this study, (c) description of the fauna, (d) comparison with other faunas, and (e) paleoecology.

Paleoecological studies are approached in the following ways: (a) taphonomic studies: size frequency distributions and the nature of preservation are used to try to discriminate between transported faunas and *in situ* faunas, (see Whatley 1988a for full details), (b) functional morphology: some aspects of ostracode morphology, such as shape and ornament, can be useful paleoecological indicators, and (c) recognition of recurrent associations between ostracode biofacies and lithofacies, that can enable paleoenvironmentally useful faunal criteria to be developed.

Because this chapter attempts to present an uncluttered overview of the faunas, detailed documentation of the samples, sampling localities and the preparation techniques used can be found in appendices 1-3 at the end of the thesis.

Scope of the study.- Although this thesis succeeds in its primary aim, a thorough taxonomic documentation of the ostracode faunas of the study areas, it is less successful in achieving its secondary objectives.

Use of ostracodes as paleoenvironmental indicators, for example, was beset by a number of problems including: (a) differences in origin of the collections: unrecorded information, such as sample size and the proportion of the fauna extracted, could not be obtained for the Carter Collection, (b) wide variations in sample and collection sizes, making comparisons difficult, (c) differences in preparation techniques: no valid conclusions can be reached by comparing the number of specimens in vibra-tool prepared and washed collections, because vibra-tool preparation is slow and selective, while washing is quick and unselective, (d) differences in the age of the faunas: the faunas of the three study areas are not contemporaneous, but range in age from the Llanvirnian to the Ashgillian, (e) facies bias of samples: because readily processable rock types were selected, the ostracode

collections only give a partial picture of the overall faunas, (f) poor understanding of the sedimentary environments of the sampled lithofacies, and (g) the general lack of knowledge of Ordovician ostracode paleoecology.

Because of these sampling and preparation biases, quantitative comparison of the number of specimens in the different collections is considered invalid. Consequently a qualitative and practical approach to ostracode paleoecology is adopted here. It was not possible to recognise any recurrent associations between ostracode biofacies and lithofacies, so all the paleoenvironmental comments are based on observations of the nature of the faunas, their taphonomy, and the sedimentology of the studied strata.

It is not possible to develop a comprehensive paleoenvironmental interpretation using ostracodes alone. Ostracodes can however, be used to support or rebuff an existing paleoenvironmental interpretation, which should be based on a wide variety of sedimentological and paleontological evidence. Thus, the sections on paleoecology use the ostracode faunas to support or reject the paleoenvironmental interpretations that are given in Chapter 2.

INTRODUCTORY COMMENTS ON THE FAUNAS

Taxonomy.- In this writer's opinion, faunas are subdivided into too many species in the literature, and a number of the taxa described are synonymous. Some new species have been established without carefully investigating the existing taxa in the literature. As a consequence, there are many synonyms in the literature, and faunas are more similar than has been supposed.

Because of this perceived oversplitting, a number of existing species are lumped together here. No new species were established during this study because of the wealth of existing taxa, limited material, and uncertainty over whether some

specimens are dimorphs or juveniles. Complete details of the suprageneric classification scheme adopted, and the species identified can be found in Chapter 6.

Mode of life of the ostracodes.- Although little has been written on the mode of life of Ordovician ostracodes, it is possible to speculate on their functional morphology, by comparison with modern analogues. Because environmental adaptation holds the key to the evolution of the wide variety of shapes and structures found in ostracodes, there is a close relationship between ostracode morphology and mode of life. Benson *in* Moore (1961, p. Q60) noted the following relationships between ostracode morphology and mode of life: (a) burrowers tend to be smooth and elongate, (b) swimmers are generally smooth, thin-shelled and relatively short, and (c) crawlers are often highly ornamented and have strong, thick valves with flat venters.

Lower Paleozoic ostracodes probably lived and behaved like typical modern forms, as benthic crawlers or swimmers, and some taxa may have adapted to infaunal life-styles (Siveter 1984). Pelagic ostracodes are unknown in the Ordovician, and are first reported with certainty in the Silurian (Siveter 1984; Siveter *et al.* 1987). Because of their relatively heavy, robust, lobate carapaces, flattened ventral margins, weight distributing projections (e.g., frills, ridges, spines) and sub-triangular cross-sections, most palaeocopids were undoubtedly benthic crawlers (Henningsmoen 1965; Siveter 1984). The convex ventral margins of many palaeocopids may indicate that they could swim short distances, on or near the bottom (Siveter 1984). Their shape suggests that the smooth-shelled podocopes, metacopes and platycopes, include benthic crawling, swimming and burrowing forms (Siveter 1984). Vannier (1990) recently commented on the mode of life of the leiocopes; he suggested they were benthic dwellers, with limited mobility, that lived on or in the substrate.

Several authors have speculated on the feeding habits of lower Paleozoic ostracodes. Most modern ostracodes are either detrital scavengers or filter feeders

(Cannon 1927, 1933; Elofson 1941; Keen 1977). After comparing the ventral margins of modern filter and detritus feeders, Adamczak (1969) suggested that most palaeocopids were filter feeders, while most baidiocyprids were detritus feeders.

Because dimorphism is such a characteristic feature of the palaeocopids, the function of the various dimorphic features (e.g., frills and loculi) has attracted considerable attention (e.g., Jaanusson 1957, pp. 197-209; Henningsmoen 1965, pp. 353-368; Ivanova 1979a; Schallreuter 1983b). Although a number of authors have speculated that dimorphic structures retain eggs or act as brood chambers, the real function of these structures remains uncertain.

Discovery of modern palaeocope-like taxa or improvements in our knowledge of the soft-part biology of key analogous forms (e.g., *Loculicytheretta*) are needed to confirm or repudiate current speculation on the functional morphology of lower Paleozoic ostracode shells (Siveter 1984).

All the ostracodes investigated during this study are benthic. On the basis of their morphology, smooth elongate ostracodes like *Phelobythocypris* can be interpreted as infaunal burrowers, while smooth, round and thin-shelled ostracodes like *Aechmina* and *Schmidtella* may be nektobenthic and capable of swimming short distances. Relatively heavy, robust and lobate tetradellids like *Tetradella*, *Foramenella* and *Tallinnella*, that have flattened venters, probably crawled on the sediment surface. Eurychilinids, like *Eurychilina* and *Platybolbina*, with their weight distributing and stabilising frills, sub-triangular cross-section and low center of gravity were probably also benthic crawlers. Although it has been studied thoroughly, the mode of life of the tetradellid, *Ceratopsis* is uncertain. Berdan and Balanc (1985, p. 14) suggested that the function of the speral process in *Ceratopsis* was as an anchor for the animal while it was feeding, and in support of this hypothesis, they note that species of *Ceratopsis* from harder substrates have short speral processes while species of *Ceratopsis* from softer substrates have longer speral processes.

Biostratigraphy.- Recognition of correlatable ostracode-based biozones, based on range charts, was not possible because: (a) most of the samples are not from continuous sections, (b) collection sizes are small, (c) the appearance and disappearance of taxa often coincide with changes in rock type, rather than with the taxa's evolution or extinction, (d) the sampled strata vary widely in age. Although no ostracode-based correlations are made, the sections on the faunas of the various study areas, include comparisons with age-equivalent faunas elsewhere. The biostratigraphic utility of Ordovician ostracodes is discussed in Chapter 4.

Comparison between the faunas of the study areas.- It is difficult to make direct comparisons between the faunas of the study areas, because of differences in their age, the preparation methods, and the intensity of sampling. However, a few general comments can be made. All the study areas have distinctive ostracode faunas, and the faunas of each area differ in terms of abundance, diversity, preservation and composition. Most species were only found in one area, but some are more widespread and were found in at least two of the study areas. *Tetradella quadrilrata* (Hall and Whitfield 1875), for example, was found in the Long Point Group, western Newfoundland, the Jolliet Group, Anticosti Island, and the Trenton Group, St. Lawrence Lowlands. Although most species were only found in one of the study areas, none of them can be described as endemic, since nearly all of the present taxa have been reported elsewhere in North America.

WESTERN NEWFOUNDLAND

TABLE HEAD GROUP

Previous studies.- Large, easily seen, leperditiid ostracodes are common in the Table Head Group. These ostracodes were first reported by Billings (1865, pp. 299-300), and have been noted in subsequent descriptions of the geology of the group (Schuchert and Dunbar 1934; Klappa *et al.* 1980; Stenzel *et al.* 1990). Although no detailed descriptions of the faunas have been made, Berdan (*in* Whittington and Kindle 1963, p. 747 and *in* Ross and James 1987, p. 95) has identified the ostracodes in a series of spot samples from the Table Head Group.

This study.- In the summer of 1988 one week was spent sampling the Table Head Group at Table Point (Fig. 5). The previously published log of Williams *et al.* (1987) was used during sampling (see Appendix 3.1). Eleven samples (T-1 to T-11) were collected; these samples fall into the following four categories: (a) samples with visible ostracodes for vibra-tool preparation, (b) samples of bedding planes with signs of silicification, such as upstanding or weathered out fossils, for hydrochloric acid preparation, (c) samples of chert for hydrofluoric acid preparation, and (d) samples of weathered limestone for washing. Vibra-tool preparation was the only technique which met with general success; the samples of weathered limestone (T-4 and T-5) also yielded ostracodes after washing. Acid preparation techniques were unsuccessful.

Description of the fauna.- Table Head Group faunas are considered in stratigraphical order. First, the common and readily collectable ostracodes of the Table Point Formation and second, the rarer ostracodes of the Table Cove Formation. The faunal abundances of the various samples taken at Table Point are summarised in Fig. 12.

TABLE POINT FORMATION.- Ostracodes from the Table Point Formation are well preserved. All the specimens have their original shells and are often infilled with calcite. Ostracodes occur throughout the Table Point Formation, but are more common in the thinly bedded, argillaceous limestones that occur in the lower and middle part of the formation, than in the massive pseudoconglomeratic limestones which form the upper part of the formation. The most common ostracode in the formation is the leperditiid *Bivia bivia* (White 1874). *Bivia bivia* is most abundant in the middle of the formation, where it sometimes occurs as large, virtually monospecific populations. Some bedding planes, like those 85 and 175 m above the base of the formation, are crowded with thousands of randomly oriented and disarticulated valves of *Bivia bivia*. Associated with *Bivia bivia* is the rarer leperditellid *Leperditella rex* (Coryell and Schenck 1941). Two large (about 10 kg each) grab samples of weathered limestone were taken from the cliff-tops at Table Point. These samples (T-4 and T-5) yielded a well-preserved washed fauna, consisting of over two hundred and twenty specimens of the species, *Aparchites* sp. and *Leperditella rex*.

TABLE COVE FORMATION.- The only ostracodes found in the Table Cove Formation were the fifteen specimens of the eurychilinid, *Eurychilina subradiata* Ulrich 1890 that were found in samples (T-10 and T-11) of trilobite-hashes from the top of the formation.

Comparison with other faunas.- The ostracode assemblage found in the Table Head Group is one of the best examples of a Whiterockian (Llanvirnian), circum-cratonal

	T–1	T–2	T–3	T–4	T–6	T–7	T–8	T–9	T–10	T–11
				T–5						
Bivia bivia	P	P	*10	*15	P	*10		P		
Eurychilina subradiata									9	6
Aparchites sp.				>70						
Leperditella rex	P	P	*10	>150	P	*5		P		

Fig. 12. Faunal abundances for the samples taken of the Table Head Group, western Newfoundland.
P = Specimens present in the sample but not prepared during this study.
★ = Number of specimens prepared from the sample.

fauna. These cratonal faunas were first recognised by Copeland (1977a, 1978); they consist of few species, but are typified by the leperditiid, *Bivia bivia* (White 1874) and the eridostracan, *Cryptophyllus magnus* (Harris 1931). Similar ostracode assemblages can be found in other early Middle Ordovician circum-cratonal settings, like the Sunblood Formation of northwestern Canada (Copeland 1974) and the Pogonip Group of Nevada (Berdan 1976).

Paleoecology.- The muddy limestones that make up most of the Table Point Formation have been interpreted as shallow, subtidal, shelf deposits (Stenzel *et al.* 1990). The presence of large numbers of leperditiids in the formation confirms this interpretation, since leperditiids like *Bivia bivia* are good indicators of very shallow-water conditions (Berdan 1981, 1984). Table Point leperditiids occur as large, virtually monospecific populations. Today, similar low-diversity, high-productivity ostracode faunas occur in adverse environments where competition is limited (Pokorný 1978). In the case of the lower and middle parts of the formation, this may indicate that we are dealing with an extremely shallow, yet fully marine environment. Because leperditiids are such good indicators of shallow marine conditions, the abrupt decrease in leperditiid numbers in the upper Table Point Formation confirms that the formation was deposited in a series of progressively deepening environments. Apart from the leperditiids, two other species, *Aparchites* sp. and *Leperditella rex* occur in the Table Point Formation. Both species have reasonably well developed instar patterns indicating that this low-diversity assemblage is *in situ*, and has been subject to little *post mortem* transport.

Ostracodes are much rarer in the overlying Table Cove Formation and only one species, *Eurychilina subradiata* was found. *Eurychilina subradiata* is unlikely to have been living *in situ*, and was probably transported downslope by a turbidity current into the distal-slope environments of the upper Table Cove Formation.

LONG POINT GROUP

Previous studies.- Although large, visible, leperditiid ostracodes have been reported from the Lourdes Formation by a number of authors (Schuchert and Dunbar 1934; Sullivan 1940; Corkin 1965; Weerasinghe 1970; Shaikh 1971; Bergström *et al.* 1974), the only study of palaeocopid ostracodes from the formation was by Copeland *in* Copeland and Bolton (1977). Copeland described a washed fauna from the basal shale of the Beach Point Member that consists of nine species, one of which, *Tetradella newfoundlandensis* Copeland 1977, was new. Copeland described the fauna as "sparse and represented by relatively few specimens" and noted that many of the taxa were typical of the mid-Middle Ordovician "Decorah" fauna that occurs over most of midcontinental North America. Ostracodes have never been reported from the Winterhouse Formation.

This study.- During the summer of 1988 about six weeks were spent doing fieldwork in the Long Point area (Fig. 6). The Long Point Group was originally the sole focus of research for this thesis, and was subject to more intense field investigation than any of the other study areas. Logs were made of the entire Long Point Group (appendices 3.2 and 3.3) and samples (L-1 to L-30) were taken throughout the succession. Particular attention was paid to sampling rocks which would be susceptible to break-down during washing. Two large samples (L-8 and L-9) of over 20 kg were taken from the shaly base of the Beach Point Member close to where Copeland and Bolton (1977) obtained their fauna. Hydrochloric and hydrofluoric acid preparation techniques were tried unsuccessfully on a large number samples. The only visible ostracodes found during handlens examination of outcrops and microscope inspection of samples, were the large leperditiids that occur in the upper part of the Black Duck

Member. Despite thorough searching and sampling, the only ostracodes found in the Winterhouse Formation were a few crushed and unidentifiable leperditiids in sample L-21.

Description of the fauna.- Apart from a few large leperditiids, the only ostracodes found in the Long Point Group were two sparse faunas washed from the shaly bases of the Black Duck and Beach Point members. Although large quantities of washed residue were picked, specimen yields were very low, and both the Black Duck and Beach Point faunas are represented by relatively few specimens. Most of the specimens are poorly preserved internal moulds or steinkerns; specimens are often corroded and sometimes flattened. The faunal abundances of the various samples taken at Long Point are summarised in Fig. 13.

BLACK DUCK FAUNA.- This previously unreported fauna consists of the four species found in samples L-2 and L-4; it is dominated by the three species, *Tetradella? newfoundlandensis* Copeland 1977, *Schmidtella* sp. and *Eridoconcha rugosa* Ulrich and Bassler 1923. A few large leperditiid valves were found in the reefal-bioherm facies that forms the upper part of the Black Duck Member (L-7). These leperditiids are commonly found in association with small brachiopods on fossiliferous bedding planes.

BEACH POINT FAUNA.- Samples (L-8, L-9, L-10 and L-11) of the weathered blue-grey shale at the base of the Beach Point Member yielded a low-diversity fauna consisting of only thirteen species represented by a total of two hundred and sixty-three specimens. The most common species, *Euprimitia labiosa* (Ulrich 1894), *Winchellatia* sp., *Tetradella? newfoundlandensis* Copeland 1977, *Aparchites fimbriatus* (Ulrich 1892), *Schmidtella* sp. and *Eridoconcha rugosa* Ulrich and Bassler 1923, were all reported in Copeland and Bolton's (1977) earlier study. In addition to these taxa,

	L–1	L–2	L–3	L–4	L–5	L–6	L–7	L–8	L–9	L–10	L–11	L–12	L–13	L–14	L–15
Eoleperditia fabulites							5								
Euprimitia labiosa								7	8	35					
Sigmobolbina? sp.								1							
Winchellatia sp.								23	17	1	10				
Tetradella quadrilirata								3		3	4				
Tetradella? newfoundlandensis		3		24				5		10					
Aparchites fimbriatus								15							
Saccelatia arrecta								4	5		2				
Schmidtella sp.		11		7				10	25	20	16				
Ectoprimitia? sp.									4						
Eocytherella? sp.									2	1					
Eridoconcha rugosa		5		6				3	10	12					
Cryptophyllus oboloides				3					4						
Balticella deckeri								3							

	L–16	L–17	L–18	L–19	L–20	L–21	L–22	L–23	L–24	L–25	L–26	L–27	L–28	L–29	L–30
Eoleperditia fabulites															
Euprimitia labiosa															
Sigmobolbina? sp.															
Winchellatia sp.															
Tetradella quadrilirata															
Tetradella? newfoundlandensis															
Aparchites fimbriatus															
Saccelatia arrecta															
Schmidtella sp.															
Ectoprimitia? sp.															
Eocytherella? sp.															
Eridoconcha rugosa															
Cryptophyllus oboloides															
Balticella deckeri															

Fig. 13. Faunal abundances for the samples taken of the Long Point Group, western Newfoundland.

two more species, *Tetradella quadrilirata* (Hall and Whitfield 1875) and *Balticella deckeri* (Harris 1931), are reported for the first time.

Comparison with other faunas.- As Copeland and Bolton (1977) noted, the Beach Point fauna is less diverse than, but very similar to, other North American platformal faunas of comparable age. Most of the species have been reported elsewhere, particularly from the central and eastern North American faunas described by Kay (1934, 1940), Harris (1957), Kraft (1962), Swain (1962) and Copeland (1965). The taxa, *Tetradella quadrilirata* and *Balticella deckeri*, confirm the similarity of this fauna to other North American Middle Ordovician faunas. *Tetradella quadrilirata*, for example, is extremely widespread and has been reported from Middle and Upper Ordovician strata all over North America. *Balticella deckeri* is less common, but has been documented from the Middle Ordovician of Oklahoma (Harris 1931, 1957), Virginia (Kraft 1962) and Pennsylvania (Swain 1962).

Paleoecology.- Before discussing the paleoenvironmental implications of the faunas, it is worth considering whether ostracodes really are confined to the readily washable basal shales of the Beach Point and Black Duck members. Could this faunal occurrence pattern simply reflect the availability of processable rock types? This is considered unlikely for the following reasons: (a) in the field, all rock types were carefully searched for ostracodes with a handlens, and (b) all samples which did not break-down were broken into small pieces and examined microscopically. Ostracodes were not found in either case, and the results from the sampling programme are thought to reflect the actual distribution of ostracodes.

The Beach Point and Black Duck faunas are not *in situ* faunas, but have been transported some distance. There are two pieces of evidence for this: (a) the most common species do not have well developed instar patterns, and (b) many specimens

are corroded, showing that they have been transported. Since these faunas are not *in situ*, it is not possible to use them to support or reject the existing paleoenvironmental interpretations of the Long Point Group, that are summarised in Chapter 2.

The distribution of ostracodes in the Lourdes Formation is interesting. Why are ostracodes only found in the shaly bases of the Beach Point and Black Duck members and not in the limestones which make up the rest of the formation? If we accept that this is not sample bias, then the most likely explanations are that: (a) ostracodes were more common in deeper parts of the shelf than in shallower parts of the shelf, and (b) ostracode diversity and speciation rates increased during the transgressive events, that the shaly bases of the Beach Point and Black Duck members record. The absence of palaeocopid ostracodes in the limestones which make up the bulk of the Lourdes Formation indicates that they probably accumulated in very shallow, high-energy, nearshore environments.

The association between leperditiids and the shallow-water, reefal-bioherms of the Black Duck Member, confirms Berdan's (1981, 1984) interpretation of leperditiids as indicators of very shallow, marine conditions.

The lack of ostracodes, apart from a few broken leperditiids, in the Winterhouse Formation supports the existing interpretation (Fåhræus 1973) of the formation as a shallow-water, possibly intertidal, deltaic sequence.

ANTICOSTI ISLAND

Previous studies.- Research on Anticosti's well-preserved lower Paleozoic ostracodes has been sporadic. Billings (1866) was the first to study ostracodes from the Anticosti

Island. He described the two taxa, *Beyrichia decora* and *Beyrichia venusta*, from samples of the Jupiter Formation that had been collected by Richardson (1857). Several of T.R. Jones' papers (e.g., Jones 1858a, 1884, 1890b) include descriptions of new Ordovician and Silurian ostracodes from Anticosti Island. Of note is his report (Jones 1890a, pp. 546-550) on Dr. G.J. Hinde's collection, which includes the first descriptions of Anticosti's Ordovician ostracodes. Schuchert and Twenhofel (1910) and Twenhofel (1921, 1926, 1928) were the first to systematically collect Anticosti's strata for fossils; ostracodes from their collections were described by Ulrich and Bassler (1923a, 1923b) in the *Maryland Geological Survey, Silurian Volume*. Twenhofel's (1928) *Geology of Anticosti Island* includes notes by Bassler (pp. 340-350) on the Island's ostracode faunas.

Nothing further was written on Anticosti's ostracodes until the early seventies, when Copeland published the first in a series of papers on Anticosti's Ordovician (Copeland 1970, 1970a, 1973, 1983) and Silurian (Copeland 1974a, 1982a) ostracode faunas. Copeland (1981) recognises two morphologically and temporally distinct faunas: an older, predominantly Ordovician, hollinacean fauna and a younger, Silurian, beyrichiacean-zygobolbid fauna. This latest Ordovician, hollinacean dominated fauna occurs throughout the Vauréal and Ellis Bay formations, as well as in the lower 35 m of the Becscie Formation, and is assigned to the *Jonesites semilunatus* Zone (Copeland 1973, 1981). The sparse fauna of the Vauréal Formation is made up of genera such as *Aechmina*, *Jonesites*, *Ulrichia*, *Leperditella*, *Ceratopsis* and *Tetradella* (Copeland 1970) which are common in age-equivalent strata of the North American craton. Although many of these genera are also found in the Ellis Bay Formation, they are accompanied by a distinctive group of genera like *Foramenella*, *Platybolbina* and *Steusloffina* which are unique in North America, and had only previously been reported from Baltoscandia (Copeland 1973, 1981). Much of this hollinacean dominated fauna, including all the tetradellids and eurychilinids,

disappears abruptly in the lower Becscie Formation and is replaced by an endemic, earliest Silurian, zygobolbid fauna (Copeland 1981).

The faunas of Anticosti's subsurface succession are poorly known. Ostracodes have been noted in drill cores (Copeland *in* Bolton 1970a, p. 33), but they have not been described and their stratigraphic distribution remains uncertain.

In summary, Copeland's most important contribution has been to document in detail Anticosti's Ordovician and Silurian ostracode faunas. His work was the first systematic investigation of Anticosti's microfaunas and although mainly taxonomic, includes valuable insights on faunal provincialism. Copeland also established a series of biozones (summarised in Copeland 1981, p. 186). The boundaries of these zones often coincide with changes in lithology, indicating that faunal change is controlled by environmental change.

This study.- Sampling was carried out in two areas of Anticosti (Fig. 7), during a nine day visit to the Island in the summer of 1989. Samples were taken along the Oil River section following Bolton's (1961) log and in the Port Menier area using the field guide edited by Lespérance (1981a). Sampling horizons are illustrated on a composite section through Anticosti's Ordovician succession in Appendix 3.4. No visible ostracodes were seen in the field and the sixteen samples taken (A-1 to A-16), were of readily washable shales, shaly interbeds or weathered limestones.

Description of the fauna.- Anticosti's Ordovician ostracodes are considered in stratigraphical order here. First, the sparse faunas of the Vauréal Formation and second, the far more abundant faunas of the Ellis Bay Formation. A complete summary of the faunal abundances for the samples taken can be seen in Fig. 14.

VAURÉAL FORMATION.- Samples (A-1 to A-6 and A-8) of the blue-grey shales that occur throughout the Vauréal Formation yielded a sparse ostracode fauna when

washed. The one hundred and forty-nine specimens which make up this fauna are moderately well preserved and usually have their original shells. This Vauréal fauna consists of seven species, the most common of which are: *Ceratopsis* sp., *Jonesites semilunatus* (Jones 1890), *Warthinia nodosa* (Ulrich 1890), *Schmidtella sublenticularis* (Jones 1890) and *Phelobythocypris cylindrica* (Hall 1871). Although the Vauréal succession was deposited in a series of progressively shallowing environments, its ostracode faunas are remarkably consistent and all the samples taken contain a low-diversity, binodicopid-rich fauna.

ELLIS BAY FORMATION.- Nine samples (A-7 and A-9 to A-16) were collected from the Ellis Bay Formation. These samples were easily processed and yielded large ostracode collections (about one thousand six hundred and fifty specimens). Preservation of these distinctive ostracodes varies from very good to excellent. The boundary between the Vauréal and Ellis Bay formations is marked by rapid increases in both faunal diversity and abundance. Several Vauréal species (*Ceratopsis* sp., *Lambeodella?* sp. and *Warthinia nodosa*) disappear and the low-diversity, binodicopid-rich Vauréal fauna is replaced by the more diverse, tetradellid-rich Ellis Bay fauna. The most characteristic species of this fauna are: *Platybolbina shaleri* Copeland 1973, *Tetradella quadrilirata* (Hall and Whitfield 1875), *Foramenella phippsi* Copeland 1973, *Anticostiella ellisensis* Copeland 1973, *Hallatia canadensis* (Bassler 1928) and *Tubulibairdia jolietti* Copeland 1973. In the Ellis Bay Formation, ostracode faunal abundances and diversities are higher in the shaly limestone members (1, 3, 5), than in the limestone members (2, 4, 6), and all new taxa make their first appearances in the shaly limestone members. It is unlikely that sampling bias could account for these observations, so the nature of the faunas was controlled by the type of sedimentary environment.

	A–1	A–2	A–3	A–4	A–5	A–6	A–7	A–8	A–9	A–10	A–11	A–12	A–13	A–14	A–15	A–16
Bolbiprimitia? schmitti							1								4	
Platybolbina shaleri												2				39
Tetradella quadrilirata							28								23	94
Foramenella phippsi							7			21	17	4	85	5	95	104
Anticostiella ellisensis	1						21		3	3	2			2	3	16
Ceratopsis sp.		8														
Lambeodella? sp.					2	3										
Aechmina maccormicki							29		9							
Jonesites semilunatus		3	2	10			>355	6	14	1	3		15	2	15	12
Warthinia nodosa	3			3	4											
Schmidtella sublenticularis	23	10	3				154	2	58		5	6	11	8	40	58
Hallatia canadensis												4				42
Cryptophyllus oboloides							3								2	
Phelobythocypris cylindrica		8	17	8	13	12	30	8	8	24	7	5		21	13	14
Tubulibairdia jolietti							2		11		5			9	16	33
Eographiodactylus hyatti											1				2	

Fig. 14. Faunal abundances for the samples taken on Anticosti Island.

Comparison with other faunas.- Copeland's (1970, 1973) faunas consist of significantly more species than the faunas described here, because: (a) Copeland's studies were more extensive, involving work on a variety of sections over several field seasons, and (b) several of Copeland's taxa are grouped together here.

VAURÉAL FORMATION.- Most of the species found in the Vauréal Formation are widespread. Species such as *Warthinia nodosa* and *Phelobythocypris cylindrica*, occur in Middle and Upper Ordovician platformal strata throughout North America. The Vauréal faunas are however, more sparse and less diverse than comparable North American platformal faunas.

ELLIS BAY FORMATION.- Copeland (1981) described the fauna of the Ellis Bay Formation as "... a hollinacean dominated fauna... derived from North American stock...and bearing a north European tetradellid component previously unknown from North America." He went on to note that the "... presence of... *Foramenella*... a genus which is unique in North America... together with *Tetradella*, *Platybolbina* and *Diplopsis*..." provides evidence of an Upper Ordovician biogeographic link between Anticosti and Baltoscandia.

While agreeing with Copeland (1981) that the latest Ordovician faunas of Anticosti and Baltoscandia (e.g., Öpik 1936 and Sarv 1959) contain many closely related taxa, this author believes that the Ellis Bay fauna is also closely comparable with other North American Middle and Upper Ordovician faunas, and contains many of the same species as the midcontinental faunas described from Minnesota and Iowa by Ulrich (1894), Kay (1940) and Swain and Cornell (1987). Although the occurrence of *Foramenella* is unique in North America, *Foramenella phippsi* is morphologically similar to species of *Ctenobolbina* and *Dilobella* described from the Decorah Formation of Minnesota by Ulrich (1894, pp. 674-675), Kay (1940, pp. 256-257) and Swain and Cornell (1987, p. 110). Two of the other genera, *Tetradella* and *Platybolbina*, that Copeland (1981) mentions as evidence of a connection between the

Anticosti region and Baltoscandia, are also widespread in North American platformal strata. Thus, it would appear that there are no special similarities between the faunas of Anticosti and Baltoscandia, and many North American faunas contain taxa that are closely related to the taxa found in Baltoscandia.

Paleoecology.- Although Anticosti's geology has been intensively studied, little is known about the Island's paleoenvironmental history. Anticosti's ostracodes have also been well documented, but nothing has been written on either faunal paleoecology or the paleoenvironmental implications of the faunas. Because background information is limited, commenting on the paleoenvironmental significance of the faunas is problematic.

VAURÉAL FORMATION.- The Vauréal Formation records the Anticosti Basin's change from a Taconic foreland basin to a stable carbonate shelf (Barnes 1988). The upper exposed part of the formation is a cyclical, shaly carbonate sequence that was deposited in a series of progressively shallower, subtidal environments (Nowlan and Barnes 1981).

Because each Vauréal taxon is only represented by a few specimens, size dispersion diagrams could not be plotted and it is not possible to determine with certainty, whether or not the faunas are *in situ*. The following pieces of evidence do, however, suggest that the faunas have not been subject to much *post mortem* transport: (a) specimens are reasonably well preserved, (b) faunal assemblages are made up of a wide range of different sized specimens, and (c) species are represented by both valves and carapaces. Vauréal faunas are low in diversity, and are made up of three elements, binodicopids such as *Warthinia nodosa*, tetradellids like *Ceratopsis* sp. and smooth ostracodes such as *Phelobythocypris cylindrica*. This assemblage can be considered as characteristic of the deeper water, detritus-influenced, outer shelf environments represented in the Vauréal Formation. In the sampled section, ostracode

communities are stable and little faunal change occurs. Low rates of extinction and speciation may indicate that the paleoenvironment was unstable (*sensu* Bretsky and Lorenz 1970; Eldredge 1974), and less influenced by sea-level or other environmental changes than the shallower shelf environments of the overlying Ellis Bay Formation.

ELLIS BAY FORMATION.- Deposition of the Ellis Bay Formation marks a return to a pattern of stable, carbonate platform sedimentation in the Anticosti Basin (Petryk 1981b; Barnes 1988). The Ellis Bay Formation is characterized by a cyclic alternation of shaly limestones (members 1, 3, 5) deposited during transgressive events, and thinly bedded limestones (members 2, 4, 6) deposited during regressive events (Petryk 1981b). These transgressive-regressive cycles are believed to be the result of glacio-eustatic, sea-level changes associated with the North African glaciation (Petryk 1981e, 1982; Johnson *et al.* 1981).

It is unlikely that Ellis Bay ostracodes have been transported far, and the faunas can be considered to be *in situ*, because: (a) most taxa exhibit considerable size variation (e.g., *Foramenella phippsi* and *Schmidtella sublenticularis*), (b) the faunas are well preserved showing no signs of transportation, and (c) the faunas consist of valves and carapaces of both juveniles and adults, indicating that little size-sorting has taken place.

There are a number of important differences between the faunas of the Vauréal and Ellis Bay formations. The most notable is that ostracodes are more diverse and much more common in the Ellis Bay Formation than in the Vauréal Formation. This indicates that the shallower shelf environments of the Ellis Bay Formation were much more favourable for ostracodes than the deeper water environments of the Vauréal Formation. In the Ellis Bay Formation faunal abundances and diversities are higher in the shaly limestone members (1, 3, 5), than in the limestone members (2, 4, 6), and all new taxa make their first appearances in the deeper water, shaly limestone members. Thus, each transgressive event (members 1, 3, 5) is marked by a change

or re-organisation of the community structure. The most likely explanation of these changes is that transgressions increased the shelf area and the amount of niche partitioning, encouraging faunal diversification and evolution.

Ornamented ostracodes like eurychilinids and tetradellids are far more common in the Ellis Bay Formation than in the Vauréal Formation. This could imply that the stable, shallow shelf, carbonate environments of the Ellis Bay Formation were nutrient-rich, allowing heavy calcification. An alternative explanation of the abundance of ornamented taxa, is that a wide variety of benthic environments were available, encouraging a diverse series of morphological adaptations.

The nature and distribution of Ellis Bay ostracode faunas confirms that the formation is an open shelf deposit, that accumulated during a series of transgressive-regressive cycles. Faunal change and community re-organisation occur when eustatic sea-level rises increase the shelf area and the variety of niches available.

ST. LAWRENCE LOWLANDS

Previous studies.- Ordovician ostracodes have been known from the St. Lawrence Lowlands for at least a hundred and thirty years, but little has been published on them. The first author to record ostracodes from the Lowlands was T.R. Jones, who published several papers (Jones 1858a, 1884, 1891) that include descriptions of taxa from the Chazy and Trenton groups. In the only other publication on the faunas, Foerste (1924, pp. 250-255) described and figured a number of ostracodes from the Lorraine Group.

Despite the fact that it is unpublished, Carter's (1957) Ph.D thesis on *Ordovician Ostracoda from the St. Lawrence Lowlands of Quebéc*, is the single most important source of information on the faunas of the Lowlands. Carter (1957) used a vibra-tool to prepare ostracodes from drill cores and a series of spot samples; he described ninety-five species, fifty-nine of which he considered new. Many of Carter's (1957) faunal lists are included in the Québec Provincial Government geological reports on the St. Lawrence Lowlands (e.g. Clark and Globensky 1976b).

This study.- During the summer of 1989, five weeks were spent collecting ostracodes in the Lowlands (Fig. 9). The aim was to re-sample Carter's (1957) sampling localities and build upon his collections. Unfortunately both Carter's localities and ostracodes were more difficult to find than had been anticipated. Many of Carter's (1957) sampling localities (S-6 to S-24) are now inaccessible because of quarry-infilling, hydro-dams, new roads, higher river levels, etc. The localities that were re-sampled yielded few ostracodes. A number of new localities were sampled (S-1 to S-5), and some yielded well-preserved eurychilinids and tetradellids. In the field, emphasis was placed on the collection of visible ostracodes for vibra-tool preparation. Finding these ostracodes is not easy; they must be searched for with a handlens on a bed by bed basis. Great care is needed, as they are easily missed. Samples of weathered limestone and shale were also taken at several localities; none of these samples yielded ostracodes when washed. Hydrochloric acid preparation was tried on all the limestone samples, but no silicified ostracodes were found. A composite section showing the relative stratigraphic positions of the various samples from the Lowlands is given in Appendix 3.5.

Description of the fauna.- The ostracodes investigated during this study are from two sources: (a) the samples collected and prepared by the author, and (b) the Carter

Collection. All the specimens in the Carter Collection were examined, but only selected species are re-described in this thesis. The taxa selected include: (a) all the ornamented or distinctive species, and (b) representatives of all the major faunal groups. Although ostracodes were examined from the entire Ordovician succession, only the faunas of the Trenton Group were investigated in detail. Fig. 15 shows the faunal abundances for the samples collected by the author (S-1 to S-5), and the number of specimens examined from each of Carter's (1957) collections (S-6 to S-24).

Before commenting on the faunas in detail, it is important to make a few general points. Ostracodes from the Lowlands are usually well preserved and all the specimens have their original shells. Ostracodes are rare and can only be found by very careful field examination of outcrops; many obviously fossiliferous limestones do not contain ostracodes.

BEEKMANTOWN GROUP.- No outcrops of the Lower Ordovician Beekmantown Group were visited or sampled, and only one species *Isochilina* sp. from the Carter Collection (S-9) is re-described here. When ostracodes are present, they usually occur as large, monospecific populations at specific horizons (L. Bernstein, personal communication, 1990).

CHAZY GROUP.- A number of outcrops of the early Middle Ordovician Chazy Group were examined, but no ostracodes were found. One sample (S-1) of weathered arenaceous limestone was taken from the middle of the Laval Formation; it did not yield any ostracodes. Carter (1957, p. 12) reported a sparse ostracode fauna from the upper part of the Laval Formation. This fauna consists mainly of small smooth ostracodes, but also contains species of the genera, *Eurychilina*, *Leperditella* and *Schmidtella*. Carter's (1957) Chazy Group fauna is not revised in this thesis.

BLACK RIVER GROUP.- Several days were spent carefully searching exposures of the mid-Middle Ordovician Black River Group for ostracodes. The only ostracodes found were a few large smooth ostracodes in sandstone stringers at the top of the

	S–1	S–2	S–3	S–4	S–5	S–6	S–7	S–8	S–9	S–10	S–11	S–12
Eoleperditia fabulites												
Isochilina sp.									14			
Eurychilina reticulata				8								
Eurychilina subradiata				5								
Eurychilina strasburgensis				8								
Coelochilina sp.				7						2		
Platybolbina sp.												
Oepikium sp. cf. O. tenerum							5					
Euprimitia? sp.				4						9		
Tetradella quadrilirata												
Tallinnella? subquadrans								12				1
Ctenobolbina ciliata		14										
Ctenobolbina sp.												
Ceratopsis chambersi				5								
Dicranella? sp.												
Bollia subaequata												
Quasibollia persulcata												
Jonesella obscura?												
Jonesella sp.												
Aparchites fimbriatus						18						
Leperditella sp. 1											1	
Leperditella sp. 2				10	15							
Hallatia particylindrica												
Cryptophyllus sp. aff. C. oboloides				5						5		
Krausella arcuata												
Steusloffina ulrichi												

Fig. 15. Faunal abundances for the samples from the St. Lawrence Lowlands.

	S–13	S–14	S–15	S–16	S–17	S–18	S–19	S–20	S–21	S–22	S–23	S–24
Eoleperditia fabulites								5				
Isochilina sp.												
Eurychilina reticulata												
Eurychilina subradiata												
Eurychilina strasburgensis												
Coelochilina sp.												
Platybolbina sp.						5						
Oepikium sp. cf. O. tenerum												
Euprimitia? sp.						6						
Tetradella quadrilirata								20				
Tallinnella? subquadrans												
Ctenobolbina ciliata												
Ctenobolbina sp.	8											
Ceratopsis chambersi						9	16					
Dicranella? sp.								1				
Bollia subaequata			1									
Quasibollia persulcata		1								4		
Jonesella obscura?										2		
Jonesella sp.											2	1
Aparchites fimbriatus												
Leperditella sp. 1									1			
Leperditella sp. 2												
Hallatia particylindrica						4						
Cryptophyllus sp. aff. C. oboloides				2	2	15						
Krausella arcuata								46				
Steusloffina ulrichi						5						

Fig. 15. Continued from previous page.

Lowville Formation. Carter (1957) prepared several samples of the Black River Group; only his most diverse collection (S-20) was re-examined during this study. This collection from the Leray Formation consists of, *Eoleperditia fabulites* (Conrad 1843), *Tetradella quadrilirata* (Hall and Whitfield 1875), *Dicranella?* sp., *Krausella arcuata* Ulrich 1894, immature eurychilinids and smooth ostracodes.

TRENTON GROUP.- The Middle to Upper Ordovician Trenton Group contains the best developed ostracode faunas in the Lowlands. These faunas are however, difficult to find because they only occur in isolated pockets at specific horizons in a largely barren succession. The most favourable rock types for finding ostracodes are thinly bedded argillaceous limestones. Ostracodes are much more rare in: (a) clean massive limestones, and (b) parts of the succession where the shale content is high.

Basal Trenton Group sediments.- Carter (1957) did not report any ostracodes from the base of the Trenton Group. During this study, several sections of the Ouareau, Fontaine and Pont Rouge formations were examined; the only ostracodes found were some large smooth leperditellids in scour and lag deposits at the base of the Fontaine Formation (S-5).

Deschambault Formation.- Ostracodes are more common in the Deschambault Formation than in any other part of the Ordovician succession in the Lowlands. Deschambault faunas are relatively well studied and most of the distinctive taxa in this and Carter's (1957) thesis are from this formation. Ostracodes are much more abundant in the thinly bedded basal part of the formation, than in the more massive upper part of the formation.

The basal Deschambault faunas described here are from the Carter Collection (S-11 and S-18) and from a sample collected by the author (S-4). Collecting these faunas is very time-consuming, because the ostracodes occur in isolated pockets and are very easily missed. Thinly bedded, argillaceous limestones yielded the most ostracodes. The best technique for finding these faunas is to: (a) split bedding planes, (b) wet the

rock surfaces, and (c) look for ostracodes with a handlens. The most characteristic taxa in this fauna are the eurychilinids, *Eurychilina reticulata* Ulrich 1889, *Eurychilina subradiata* Ulrich 1890, *Eurychilina strasburgensis* Kraft 1962, *Coelochilina* sp., *Platybolbina* sp. and the tetradellid, *Ceratopsis chambersi* (Miller 1874). Also present are the distinctive taxa, *Hallatia particylindrica* Kay 1934 and *Steusloffina ulrichi* Teichert 1937, the smooth taxon, *Leperditella* sp. 2 and the eridostracan, *Cryptophyllus* sp. aff. *C. oboloides* (Ulrich and Bassler 1923).

Limestones of the Deschambault Formation become cleaner and more massive about 10 m above the base of the formation. During the current fieldwork, no ostracodes were found in these massive skeletal limestones. The Carter Collection (S-7, S-10, S-16 and S-17), however, contains several taxa from this part of the Deschambault Formation. The most distinctive elements of this fauna are the eurychilinids, *Oepikium* sp. cf. *Oepikium tenerum* (Öpik 1935), *Coelochilina* sp. and *Euprimitia?* sp., together with the eridostracan, *Cryptophyllus* sp. aff. *C. oboloides*.

Upper Trenton Group.- Ostracodes are rare and very difficult to find in the upper Trenton Group. They are more easily found in the lower limestone-rich parts of the upper Trenton Group, but as shale content increases up section, they virtually disappear. Only one ostracode locality (S-2) was found during the current fieldwork; the rest of the fauna described here is from the Carter Collection (S-6, S-8, S-12, S-15, S-19, S-21 and S-22). The low-diversity faunas of the upper Trenton Group differ from the more diverse faunas of the Deschambault Formation in having more binodicopids and non-locular tetradellids, and far fewer eurychilinids. The following tetradellids and bolliids are characteristic of the upper Trenton Group: *Tallinnella? subquadrans* (Ulrich 1890), *Ctenobolbina ciliata* (Emmons 1855) and *Ceratopsis chambersi*; *Bollia subaequata* Ulrich 1894 and *Quasibollia persulcata* (Ulrich 1879).

UTICA GROUP.- Only one species, *Quasibollia persulcata* (Ulrich 1879), is described from the Middle to Upper Ordovician Utica Group (S-14) here. The only

ostracodes found in field exposures of the Utica Group were some small, very poorly preserved, smooth ostracode casts. Carter (1957, pp. 20-21) examined a large number of core and surface samples from the Utica Group: he only found a sparse, probably transported, fauna that consists of a species of *Tetradella*, some smooth ostracodes and *Quasibollia persulcata*.

LORRAINE GROUP.- Carter's (1957) entire fauna from the Middle to Upper Ordovician Lorraine Group is not revised in this study. The taxa described here are the morphologically distinctive species, *Jonesella* sp. and *Ctenobolbina* sp., from the Nicolet Formation (S-13, S-23, S-24). The sparse, low-diversity fauna Carter (1957, pp. 21-23) described from the group also includes moult-retaining eridostracans and some smooth ostracodes.

QUEENSTON GROUP.- Ostracodes have never been reported from the Queenston Group in the Québec Lowlands.

Comparison with other faunas.- When Carter (1957) described his collections, he established many species on the basis of minor morphological differences. In this study most of these species are considered to be synonyms of previously described species, and are lumped into the most appropriate pre-existing taxon. Carter (1957) constructed a series of species range charts, which do not in this author's opinion reflect the true ranges of his taxa, because: (a) his fauna is subdivided into too many species on the basis of minor morphological differences, (b) the ranges given are often based on very limited numbers of specimens, (c) most of Carter's samples are from spot localities, rather than continuous sections, and (d) faunal appearances and disappearances often coincide with rock type and consequently paleoenvironmental changes, rather than with the taxon's evolution or extinction. Given these problems, it is not possible to make any valid ostracode-based correlations using Carter's (1957) range charts.

Although this thesis includes descriptions of ostracodes from the entire Ordovician succession in the Lowlands, only the faunas of the Trenton Group were investigated comprehensively. Given this constraint, valid comparisons with faunas elsewhere can only be made for the Trenton Group faunas, which are typical North American Middle Ordovician platformal faunas. Similar faunas have been described from various parts of eastern and central North America by Ulrich (1890, 1894), Kay (1934, 1940), Kesling (1960), Kraft (1962), Copeland (1965), Copeland *in* Steele and Sinclair (1971), Warshauer and Berdan (1982) and Swain and Cornell (1987). Many Trenton species, such as *Eurychilina reticulata*, *Eurychilina subradiata*, *Ceratopsis chambersi* and *Hallatia particylindrica* are very widespread and are common in the Middle and Upper Ordovician strata of midcontinental North America. Many of the genera found in the Trenton Group, such as *Eurychilina*, *Coelochilina*, *Platybolbina*, *Oepikium* and *Tallinnella* are also found in the Baltoscandian faunas described by Öpik (1936), Jaanusson (1957) and Vannier *et al.* (1989). This indicates that: (a) faunas are less endemic than has been assumed, and (b) some taxa were very widespread in the Ordovician shelf seas.

Paleoecology.- Trenton Group faunas are thought to be *in situ* because: (a) the only species with a large number of specimens, *Ceratopsis chambersi*, exhibits wide size variation, (b) the faunas are well preserved showing no signs of transportation, and (c) the faunas consist of valves and carapaces of both juveniles and adults, indicating that little size-sorting has taken place.

BASAL TRENTON GROUP SEDIMENTS.- Basal Trenton Group sediments have been interpreted as shallow, nearshore, platformal deposits (Parker 1986; Mehrtens 1988). The only ostracodes found in these sediments were the large, robust leperditellids in sample S-5. The robust nature of these ostracodes, and the very low diversity of the

fauna, confirms that the basal Trenton Group was deposited in a shallow, high-energy, unstable, nearshore environment.

DESCHAMBAULT FORMATION.- Ostracodes, particularly ornamented forms like the eurychilinids and tetradellids are relatively common in the basal 10 m of the Deschambault Formation, but are much less common in the remainder of the formation. Mehrtens' (1988) interpretation of the formation as a shallow-water, carbonate build-up with both core and flank facies, helps explain the distribution of ostracodes in the formation. The thin-bedded, argillaceous limestones at the base of the formation are flank facies, while the more massive, cleaner limestones which make up the rest of the formation are core facies. The core facies are dominated by relatively high-energy, cross-bedded, skeletal sands, while the flank facies consists of lower energy, deeper water, bioclastic, carbonate muds. Ostracodes apparently preferred the relatively stable, lower energy habitats along the margins of the carbonate build-up, rather than the higher energy, relatively unstable environments of the carbonate build-up.

UPPER TRENTON GROUP.- Ostracodes are much rarer in the ramp facies of the upper Trenton Group, than in the shelf facies of the Deschambault Formation. Ostracodes in general and ornamented forms in particular, become increasingly rare through the upper Trenton Group. Because the group accumulated on a subsiding ramp with progressively increasing water depth (Mehrtens 1988), the distribution of ostracodes would appear to be depth related.

CHAPTER 4

ORDOVICIAN OSTRACODES
A REVIEW

INTRODUCTION

Introduction.- Studies of Ordovician ostracodes have been almost entirely confined to North America (Fig. 16) and Europe (Fig. 17). Between the 1930's and 1970's, North American faunas often received more attention than European faunas; now however most new publications are of European origin.

Because Ordovician ostracodes are poorly known, most authors have taken a taxonomic approach with little or no emphasis on paleoecology. Two recent papers are notable exceptions to this rule: In 1985, Schallreuter and Siveter reviewed ostracodal links across the Iapetus Ocean, while Vannier *et al.* (1989) synthesised the results of over ten years research on British, Baltoscandian and Ibero-Armorican ostracodes and went on to correlate faunal change with eco-tectonic change.

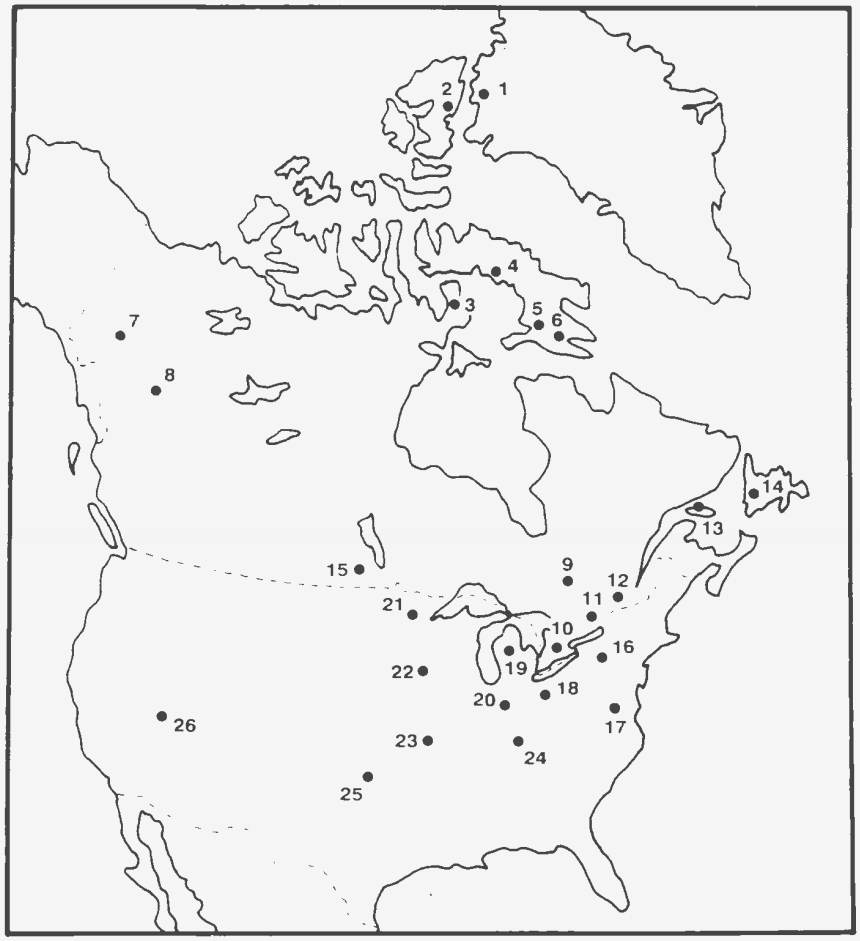


Fig. 16. Distribution of key papers on North American Ordovician ostracode faunas.

1, Greenland (Teichert 1937a); **2**, Ellesmere Island (Teichert 1937b); **3-6**, Melville Peninsula and Baffin Island (Copeland 1977c); **7**, Yukon (Copeland 1966, 1977b, 1978); **8**, Northwest Territories (Copeland 1974, 1977b, 1982, 1989); **9**, Lake Timiskaming, Ontario (Copeland 1965); **10**, Southern Ontario (Copeland 1962); **11**, Ottawa Valley (Copeland *in* Steele and Sinclair 1971; Copeland *et al.* 1989); **12**, St. Lawrence Lowlands (Carter 1957); **13**, Anticosti Island (Copeland 1970, 1973, 1981); **14**, Western Newfoundland (Copeland and Bolton 1977); **15**, Manitoba (Ulrich 1889); **16**, Pennsylvania and New York (Swain 1957, 1962); **17**, Virginia (Kraft 1962); **18**, Ohio (Guber 1962; Warshauer 1969, 1972, 1975); **19**, Michigan (Kesling 1960; Kesling *et al.* 1962; Kesling and Hussey 1953); **20**, Indiana (Guber 1962); **21**, Minnesota (Ulrich 1894; Kay 1934, 1940; Swain *et al.* 1961; Swain and Cornell 1987; Burr and Swain 1965); **22**, Iowa (Kay 1934, 1940; Burr and Swain 1965); **23**, Missouri (Keenan 1951); **24**, Kentucky (Warshauer and Berdan 1982; Berdan 1984; Berdan and Balanc 1985); **25**, Oklahoma (Harris 1931, 1957; Levinson 1961); **26**, Utah (Berdan 1976, 1988).

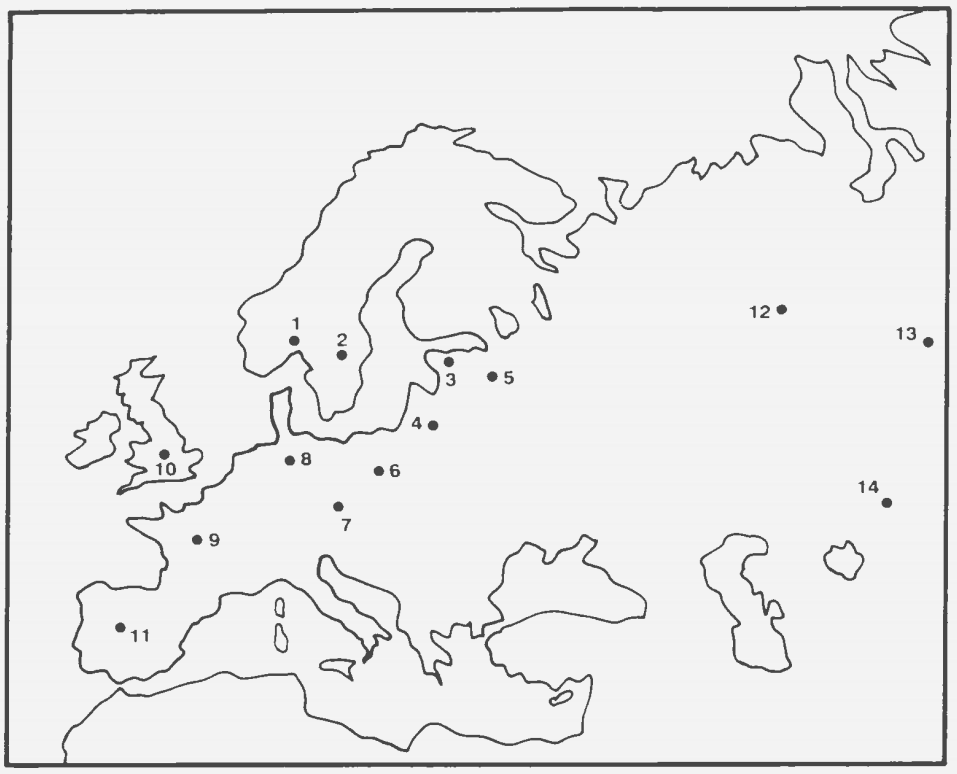


Fig. 17. Distribution of key papers on Eurasian Ordovician ostracode faunas.

1, Norway (Henningsmoen 1953b, 1954a, 1954b; Qvale 1980); **2**, Sweden (Thorslund 1940; Henningsmoen 1948; Hessland 1949; Jaanusson 1957; Schallreuter 1980); **3**, Estonia (Öpik 1935, 1936, 1940; Sarv 1956, 1959, 1962, 1963); **4**, Lithuania (Sidarvicience 1971, 1975); **5**, Eastern Baltic (Neckaja 1953, 1966); **6**, Poland (Olempska 1988, 1989); **7**, Bohemia (Přibyl 1977); **8**, Germany (Schallreuter 1971, 1973a, 1975a, 1975b, 1976, 1982, 1983a, 1984); **9**, France (Vannier 1985); **10**, United Kingdom (Spjeldnaes 1963; Siveter 1978a; Jones 1986, 1987); **11**, Iberia (Vannier 1986a, 1986b); **12**, Urals (Mel'nikova 1979a); **13**, Siberia (Kanygin 1971, 1977; Mel'nikova 1979b, 1980); **14**, Kazakhstan (Mel'nikova 1982, 1986).

The Ordovician is an important period in ostracode history: several new taxonomic groups were established (e.g., the palaeocopids), many new genera appeared and faunal turnover rates were high. Lower Ordovician faunas are rare and less well documented than those from the Middle and Upper Ordovician. The following section summarises the existing knowledge of North American Ordovician ostracodes. For an up-to-date review of European Ordovician ostracode faunas, the reader is referred to Vannier *et al.* (1989).

North American Ordovician ostracode faunas.- Despite over a century of research, knowledge of North American Ordovician ostracodes remains poor. Most of the hundred or so papers written are taxonomic descriptions of local faunas; only a few of these papers include information on the size of collections or faunal paleoecology.

Studies of these ostracodes have commonly been based on either washed, silicified or vibra-tool faunas. Each of these techniques and the samples selected for them have built-in biases, so care must be taken when comparing faunas. The following sections briefly summarise what is known about North American Lower, Middle and Upper Ordovician ostracodes:

LOWER ORDOVICIAN.- North American Early Ordovician (Tremadocian to Arenigian) ostracode faunas are poorly known and largely undocumented. The sparse faunas that have been recorded from Lower Ordovician limestones (e.g., Whitfield 1889; Berdan 1976) are dominated by isochilinids and leperditellids. No significant ostracode faunas have been reported from the widespread Lower Ordovician dolomites that occur over much of the midcontinent (Swain 1977).

MIDDLE ORDOVICIAN.- Copeland (1977a, 1978) recognises two North American Middle Ordovician ostracode assemblages. The earliest is a circum-cratonal Whiterockian (Llanvirnian) assemblage that contains few species but is typified by *Bivia bivia* (White 1874) and *Cryptophyllus magnus* (Harris 1931). This assemblage

has been recorded in various circum-cratonal settings like the Sunblood Formation of northwestern Canada (Copeland 1974), the Pogonip Group of Nevada (Berdan 1976) and the Table Head Group of western Newfoundland (Berdan *in* Whittington and Kindle 1963, p. 64; Berdan *in* Ross and James 1987, p. 95).

Succeeding the circum-cratonal fauna is the widespread Blackriverian to Edenian (Caradocian) midcontinental "Decorah fauna" (Copeland 1977a). The Decorah fauna was first described by Kay (1934) from the Decorah Shale of Minnesota and Iowa and was subsequently recognised to be widespread throughout most of North America. Similar Decorah type faunas have been reported from Ontario (Copeland 1965), Virginia (Kraft 1962), Oklahoma (Harris 1957), the Canadian Arctic Islands (Copeland 1977c), the Mackenzie Mountains (Copeland 1974, 1982) and western Newfoundland (Copeland and Bolton 1977). Decorah type faunas are found in the shaly platformal carbonates that were deposited on the North American craton following the widespread early Middle Ordovician Tippecanoe transgression (Frazier and Schwimmer 1987). Copeland (1977a) divides the Decorah fauna into two temporal sub-assemblages. He recognises an older "southern" sub-assemblage typified by the genera "*Aparchites*", *Dicranella*, *Eurychilina* and *Ceratopsis* and a younger "boreal" sub-assemblage typified by genera such as *Oepikium*, *Steusslofina* and *Levisulculus*. The boreal fauna is only slightly less widespread than the southern fauna, but shows distinct Baltoscandian affinities (Copeland 1977a).

Although about two hundred and fifty Middle Ordovician ostracode species have been described worldwide (M.J. Copeland, personal communication, 1988), a typical North American fauna consists of about sixty species representing less than forty genera. Collection sizes, often unreported, are generally small and a sample yielding more than a hundred specimens is considered good. Fig. 18 shows variations in the number of genera from selected North American Middle Ordovician ostracode faunas and breaks these faunas down into their major taxonomic components. Although the

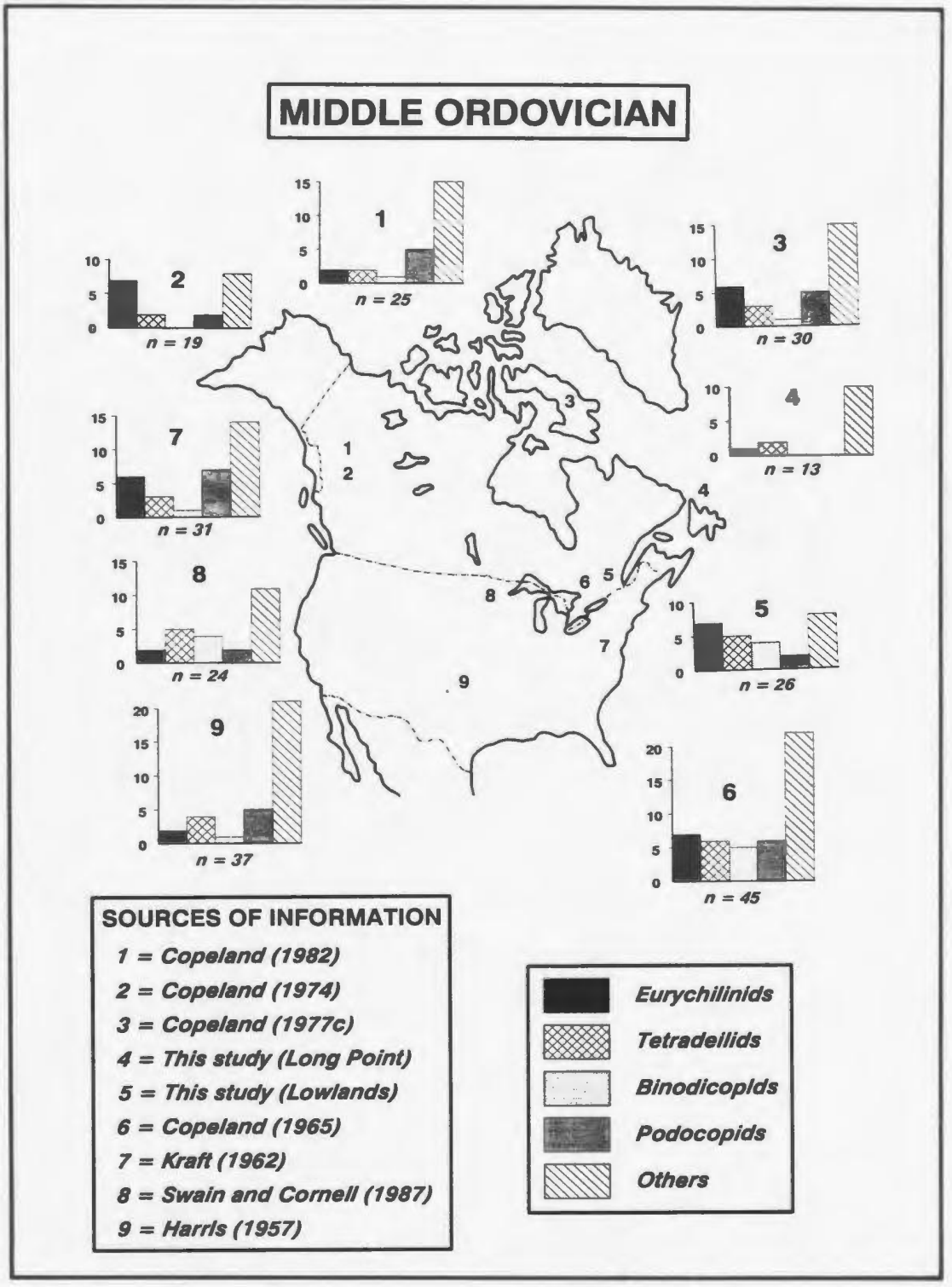


Fig. 18. Histograms showing the number of eurychilinid, tetradellid, binodicopid and podocopid genera in selected North American Middle Ordovician ostracode faunas.

percentages of podocopids, binodicopids, etc. varies, no systematic variation in the proportions of the various taxonomic components is apparent.

By the Middle Ordovician, strong ostracode faunal links had been established across the Iapetus Ocean, and genera such as *Cryptophyllus* and *Ceratopsis* are recorded from both the North American and European plates (Schallreuter and Siveter 1985).

UPPER ORDOVICIAN.- North American Upper Ordovician (Edenian to Richmondian) ostracode faunas are not well known, but have many elements in common with the older Decorah fauna. The Upper Ordovician was a period of high sea-level stand and carbonate sequences accumulated over much of the northern and central parts of the North American craton. These carbonates often contain diverse ostracode assemblages. Faunas found in Missouri (Keenan 1951), Ohio (Warshauer 1972), Kentucky (Warshauer and Berdan 1982), northwestern Canada (Copeland 1977b, 1989) and Anticosti Island (Copeland 1970, 1973, 1981) are similar, and contain many of the same genera (e.g., *Aechmina, Phelobythocypris, Jonesites* and *Tetradella*). Fig. 19 shows variations in the number of genera from selected North American Upper Ordovician ostracode faunas and breaks these faunas down into their major taxonomic components. Upper Ordovician faunas generally contain the same or slightly fewer genera than faunas from the Middle Ordovician. In addition, Upper Ordovician faunas frequently contain more binodicopid and fewer eurychilinid genera than Middle Ordovician faunas.

Very few ostracodes have been recorded from the Taconic-derived clastics that were deposited along the eastern margin of the craton during the Upper Ordovician (Swain 1977). Many genera from the Upper Ordovician of central and eastern North America also occur in Baltoscandia; for example, *Anticostiella, Tetradella, Warthinia, Platybolbina* and *Steusloffina* are found on Anticosti Island and in the Baltic (Schallreuter and Siveter 1985). The end of the Ordovician on Anticosti Island

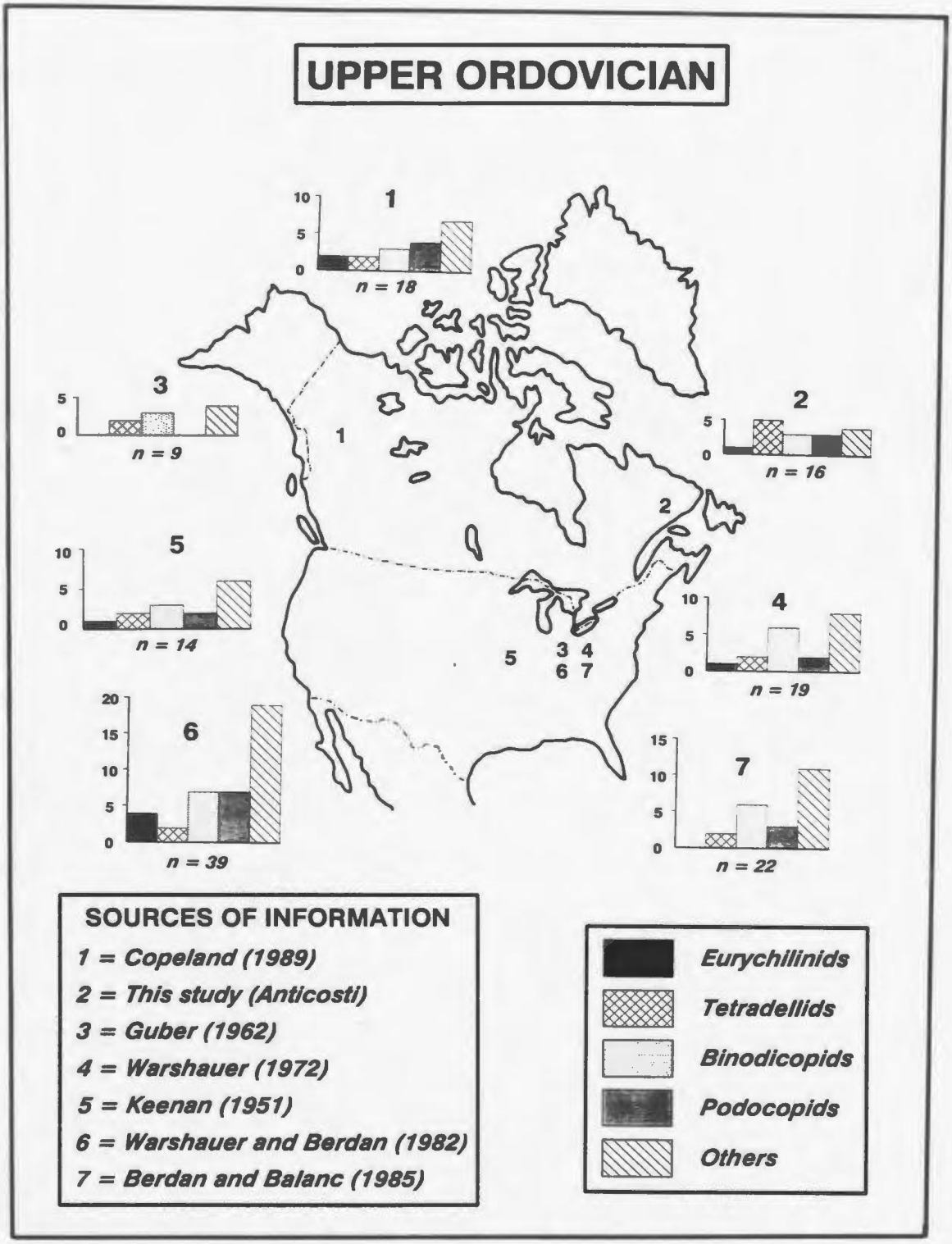


Fig. 19. Histograms showing the number of eurychilinid, tetradellid, binodicopid and podocopid genera in selected North American Upper Ordovician ostracode faunas.

is marked by the extinction of tetradellids and eurychilinids and the replacement of this predominantly hollinacean fauna with an endemic beyrichiacean-zygobolbid fauna (Copeland 1981).

TAXONOMY

Introduction.- This section discusses the present state of Ordovician ostracode taxonomy and makes a few comments on its future development. More detailed discussion of the usage and development of the various taxonomic groupings used to classify these faunas can be found at the appropriate places in the taxonomic descriptions section of this thesis (Chapter 6).

There is no real consensus amongst Ordovician ostracode workers on suprageneric classification schemes. The *Treatise on Ostracoda* (Moore 1961) is a good basic guide, but many aspects of it are out-of-date and it is currently undergoing revision. A number of classificatory problems including misidentification, synonymy and homeomorphy remain unresolved and require further work (Schallreuter and Siveter 1985). Because some criteria used for species diagnoses (like muscle scar patterns) are only discernable in specimens with near perfect preservation, taxonomic assignment of less well-preserved specimens is in some cases problematic. Much Ordovician ostracode taxonomy suffers from the splitters' mindset, whereby taxonomists work from the premise that each morphotype represents a separate species unless proved otherwise. A more constructive approach would be to put the onus on each taxonomist to demonstrate that each new taxon proposed is really justified, and is not just another ecophenotype.

Palaeocopids, which are the largest group of Ordovician ostracodes, have always presented special problems. Palaeocope taxonomy has developed in a haphazard

manner, largely as a result of *ad hoc* emendations and additions to existing classificatory schemes. The resulting taxonomy is complex and virtually unusable by anyone other than the specialist. Palaeocope taxonomy needs to be thoroughly revised, so that it meets the objectives of a wel' founded hierarchical classification (as outlined by Fåhræus 1984). Unfortunately, this kind of revision is beyond the scope of this thesis, so in the mean time it is best to proceed cautiously, by building on the existing taxonomic framework, in an attempt to achieve a more understandable and workable taxonomy.

Present work.- The number of active lower Paleozoic ostracode workers in North America can be counted on one hand. North American studies tend to be stratigraphic in nature, and often adhere closely to the taxonomic scheme laid out in the *Treatise* (1961). The two most prolific writers on North American Ordovician ostracodes over the past three decades have been Murray Copeland and Jean Berdan. Copeland has published extensively on the Silurian and Ordovician ostracodes of Canada. In addition tc describing new faunas from various localities in Canada (e.g., Copeland 1965, 1970, 1973, 1974, 1977b, etc.), Copeland has discussed the usefulness of Silurian leperditiids as biostratigraphic indicators (1976), and revicwed the lower Paleozoic ostracode faunas of eastern (1977a) and northwestern (1978) Canada. Although Berdan has published a number of important taxonomic papers on various North American lower Paleozoic ostracode faunas, her most valuable contributions have been on the complex taxonomy of the leperditiids (e.g., Berdan 1976, 1984).

At present, more Europeans than North Americans are working on Ordovician ostracodes. The three most active workers are Roger Schallreuter (University of Hamburg), David Siveter (University of Leicester) and Jean Vannier (Université de Rennes). Roger Schallreuter is currently the most prolific, having published at least two hundred papers on Ordovician ostracodes. He usually works on faunas extracted

from North German or Scandinavian erratics using hydrofluoric acid. Schallreuter concentrates on taxonomic description of his exquisitely preserved faunas and has modified the taxonomic schemes of various taxonomic groups, like for example, the Eurychilinacea (1975a) and the Tetradellidae (1982, 1983a). David Siveter principally works on Silurian ostracodes, but has published a number of papers on Ordovician ostracodes, including a useful summary of British faunas (Siveter 1978a).

There are a number of paleontologists in the Soviet Union working on lower Paleozoic ostracode faunas; unfortunately only a few are known from their publications (e.g., A.V. Kanygin, L.M. Mel'nikova, and L.I. Sarv). Acquiring translations of Soviet work is difficult, the best sources are the *Paleontological Journal* and translations held by several of the larger museums and geological surveys. Many Soviet papers suffer from their poor illustrations and the fact that their authors have only limited access to the existing literature.

To summarise, Ordovician ostracode taxonomy is currently beset by a series of problems which can be summarised as follows: (a) the general lack of knowledge of the faunas, (b) the numbers of taxa: because Ordovician ostracodes are a large and under studied group it is very difficult for any one individual to get an overall impression of the faunas, (c) ignoring parts of the fauna: some workers ignore or downplay unattractive elements of a fauna, (d) classificatory criteria: the hierarchical priority assigned to classificatory criteria has varied widely, creating taxonomic instability, (e) illustrations: poor illustrations in the past and even today, makes re-interpretation of faunas difficult, and (f) communication: communication problems are common and include, not publishing, excessive publishing, and neglect of work in languages other than one's own.

Future work.- Several suggestions are made with regard to future work. First, it is important that published taxonomic studies are based on large representative faunas

that have been studied in detail and are fully illustrated. Second, new taxa should only be established when the dimorphism and ontogeny of the taxa are completely understood, and third, care should be taken with classification criteria, so that they are easily discernable and can be readily ranked into a hierarchical sequence reflecting species, genera, etc.

The long overdue revision of the *Treatise* is underway. David Siveter is co-ordinating the rewriting of the section on Paleozoic ostracodes, which he expects to be finished in three to four years (D.J. Siveter, personal communication, 1988). The *Treatise* will re-illustrate and re-examine existing taxa, and will form the framework for future investigations of Paleozoic ostracodes.

PALEOECOLOGY

Introduction.- Because of their environmental sensitivity and occurrence in a wide variety of aquatic environments both past and present, ostracodes can be useful for the elucidation of Paleozoic paleoenvironments. Ostracode-based interpretations of these paleoenvironments are founded on both studies of the faunas themselves and on the principle of uniformitarianism, which allows us to use recent ostracode ecology as a framework for interpreting the past.

After briefly summarising the ecology of recent ostracodes, the following sections include discussions of the paleoecology of Paleozoic ostracodes in general and Ordovician ostracodes in particular.

Ecology of recent ostracodes.- Recent ostracodes have a wide ecological range, having colonized all types of aquatic environments and even some terrestrial niches.

Ostracodes now live in all types of marine environment including coastlines, continental shelves and the deep oceans.

Ocean waters today are characterised by their stratification into a thin (0-500 m) warm thermosphere that overlies the cold water masses of the psychrosphere (Benson 1988). In this two-layer ocean model the boundary between the thermosphere and psychrosphere is a formidable physical and biological barrier (Benson 1988). Below this barrier is a cosmopolitan, low-diversity and morphologically distinct ostracode fauna (Benson 1975, 1979), while on the continental shelves, above this barrier, there are highly diverse ostracode faunas consisting of thousands of provincial species which have been differentiated by the action of eustatic, climatic and tectonic processes through time (Benson 1988).

The spatial distribution and nature of modern benthic ostracode assemblages is controlled by a number of parameters, the most important of which are salinity, depth, temperature, substrate and food supply, (for further details, see: Benson 1961; Oertli 1971; Swain *et al.* 1975; Loffler and Danielopol 1977; Maddocks 1983; De Decker *et al.* 1988; Hanai *et al.* 1988; Whatley 1988).

SALINITY.- Recent ostracodes exhibit the following responses to variation in salinity in modern environments: (a) morphological variation: recent ostracode populations exhibit phenotypic variation in size, noding, ornamentation, sieve-pores and shell thickness in response to salinity variations (Kilyeni 1972), (b) variation in intraspecific population structure: in unfavourable salinity conditions marine ostracode populations reproduce less frequently (Horne 1983), reach sexual maturity earlier and may reproduce asexually (Whatley 1983), (c) differences in salinity preferences or tolerances: recent ostracode species and faunas have adapted to a wide variety of salinity conditions, from freshwater to hypersalinity, and (d) differences in diversity, dominance and productivity: recent freshwater and particularly brackish

water faunas are dominated by a few highly abundant species, unlike marine assemblages which are generally much more diverse (Pokorný 1978).

DEPTH.- Although depth in itself is not thought to affect ostracode faunas (Brasier 1980), it provides strong control on some important, interdependent ecological factors such as light penetration, food supply and water temperature, all of which influence the morphology, composition and distribution of ostracode faunas.

TEMPERATURE.- Temperature control on ostracode assemblages acts latitudinally and vertically. Latitudinal temperature control on shallow-water benthic ostracodes has been a major contributor to the formation of the numerous localised ostracode assemblages that occur from the poles to the equator (Whatley 1983). This endemism is heightened by the lack of a planktic larval stage to aid dispersal.

SUBSTRATE AND FOOD SUPPLY.- Both substrate and food supply have been noted as factors influencing the abundance, composition and diversity of ostracode faunas (Brasier 1980; Pokorný 1978).

Although the ecology of recent ostracodes has been well documented by numerous descriptions of individual faunas, there are no publications which synthesise, condense or generalise this information into well codified concepts that are usable as a basis for practical paleoenvironmental interpretation. The only texts (Pokorný 1978; Brasier 1980) which generalise on recent ostracode ecology are too simple to be practically useful. Kaesler (1983) makes the point that although ostracode specialists enthuse about the practical paleoenvironmental value of ostracodes, they overlook the fact that no one other than themselves ever uses them. There are a number of reasons for this neglect of a group which potentially has numerous practical applications. One of the obvious reasons is simply taxonomic complexity, which makes the group unintelligible to anyone other than the specialist. Indeed, it is even difficult for the ostracode specialist to keep up with anything more than a couple of families. This taxonomic complexity has been primarily caused by chronic oversplitting; Kaesler (1983)

believes that some creative lumping at generic and higher levels is needed so that the number of higher level taxa is reduced.

Paleoecology of Paleozoic ostracodes.- The paleoecology of Mesozoic and Tertiary ostracodes is often interpreted by direct comparison with the ecology of similar living taxa. Since the vast majority of Paleozoic ostracodes have no living representatives, paleoenvironmental analysis of these faunas must rely on synthesis of data from one or more of the following sources: (a) taphonomic studies: to ensure that any interpretation is based on *in situ* faunas recognition of taphonomic overprinting using size frequency distributions is essential, (b) speculation on the functional morphology: some morphological features of Paleozoic ostracodes, like sexually dimorphic structures (Henningsmoen 1965) and sieve pores (Schallreuter 1983b) have been used as paleoecological indicators, (c) comparison with modern assemblages: the same general principles apply to recent and fossil ostracode ecology, thus a knowledge of the former is essential for an interpretation of the latter, (d) recognition of faunal diversity patterns: comparison can be made between the diversity patterns of fossil and recent ostracodes, care must be taken however, because factors like shifting ecological preferences and environmental stability also influenced faunal diversity patterns in the past (Whatley 1983), (e) preservation: the manner and nature of ostracode preservation can assist in both the recognition of *post mortem* faunal transport and in paleoenvironmental reconstruction, (f) the nature of associated and/or accompanying fossils: Paleozoic ostracodes are usually associated with, or accompanied by other fossils, which can provide clues about the paleoecology of the ostracodes, (g) the nature of enclosing, overlying and underlying sediments: knowledge of the sedimentary setting in which a fossil ostracode fauna lived provides invaluable evidence of the paleoecology of the fauna, (h) the inferred paleogeography: Paleozoic ostracode provincialism and endemism are best understood in the context of

paleogeographic reconstructions, and (i) recognition of recurrent temporal or spatial associations between ostracode biofacies and lithofacies.

Knowledge of the paleoecology of Paleozoic ostracodes is limited and large areas of ignorance and uncertainty remain. Most of what we do know is in the form of generalizations based on isolated and conceivably questionable, observational evidence. Conclusions about the paleoecology of Paleozoic ostracodes should be based on thorough in-depth investigations of large faunas.

Paleoecology of Ordovician ostracodes.- During the Ordovician, ostracodes were part of the shallow marine, shelf benthos and deep-water psychrospheric ostracodes are unknown (Schallreuter and Siveter 1985). Substrate, salinity and depth were the principal influences on the distribution of Ordovician ostracode faunas (Schallreuter and Siveter 1985; Vannier 1986a, 1986b). Ordovician ostracode faunas have been described as highly endemic (McKerrow and Cocks 1976), but Schallreuter and Siveter's (1985) study of faunas from North America and Europe shows that similar faunas can be found in places separated by vast distances (both today and in the past).

Knowledge of the paleoecology of Ordovician ostracodes, especially in North America, is limited (Berdan and Balanc 1985) and is restricted primarily to the local presence or absence of taxa in a particular facies (e.g., Swain 1957, 1962), and to paleoecological inferences drawn from the enclosing sediments and associated faunas (e.g., Copeland 1982).

With the exception of the leperditiids, which are thought to have been shallow subtidal to intertidal scavengers or deposit feeders (Belak 1977; Berdan 1981, 1984), little is known about the functional morphology, mode of life and community structure of Ordovician ostracodes. Lithofacies control on ostracode biofacies is probably widespread (Schallreuter and Siveter 1985), but remains largely undocumented. Apart from Copeland (1982), who recognised an increase in the ratio of podocopids to

palaeocopids with increasing depth, no paleoenvironmental gradients have been established using Ordovician ostracodes. The only statistical study of Ordovician ostracodes in the literature is that of Warshauer and Berdan (1982) who defined a higher diversity muddy substrate assemblage and a lower diversity carbonate substrate assemblage using Q mode cluster analysis. Both Henningsmoen (1965) and Schallreuter (1983b) have speculated on aspects of the functional morphology and mode of life of Ordovician ostracodes.

In a recent review of European Ordovician ostracode faunas, Vannier *et al.* (1989) note that faunal composition and diversity varies with environment. In particular, conservative low-diversity, binodicope-rich faunas were associated with unstable clastic environments, while more diversified and frequently re-organised palaeocope-rich faunas were typically associated with carbonate sedimentation under more stable conditions.

There have been a number of papers on the paleoecology of Paleozoic ostracodes from periods other than the Ordovician. These papers, referenced below, can provide useful background information and a framework in which investigations of Ordovician ostracode paleoecology can be conducted: (a) Permian: Costanzo and Kaesler (1987), Kaesler and Denver (1988), (b) Permo-Carboniferous: Melnyk (1985), Melnyk and Maddocks (1988, 1988a), (c) Upper Carboniferous: Pollard (1966, 1969), Brondos and Kaesler (1976), Kaesler (1982), (d) Lower Carboniferous: Dewey (1983, 1983a, 1985, 1987, 1988), (e) Devonian: Becker (1971, 1977), Becker *et al.* (1974), Braun (1978, 1988), Berdan (1981a), (f) Siluro-Devonian: Lundin (1971), Copeland and Berdan (1977), Berdan (1983), (g) Silurian: Adamczak (1969, 1981), Copeland (1976), Warshauer and Smosna (1977), Siveter (1984, 1988, 1989), and (h) Cambrian: Müller (1979, 1982).

Summary and conclusions.- Current understanding of Ordovician ostracode paleoecology is poor. There are large areas of uncertainty or ignorance. More work is needed on all aspects of Ordovician ostracode paleoecology. It will be particularly revealing to see how far back we can trace the ecological patterns observed amongst modern ostracodes. Can, for instance, pelagic ostracodes be found in the Ordovician, as they have been in the Silurian (Siveter *et al.* 1987).

Other priorities should be the re-examination and synthesis of what we already know, since many of the answers we seek are in libraries, waiting to be revealed through new interpretations. It is also important that we review and test many of our past assumptions and conclusions, to find out whether they are still valid. Unless we do this we will be unable to undertake further work with any degree of confidence.

As research on Ordovician ostracodes progresses, it is worth bearing in mind that it is often wise to avoid being too specific about paleoecological interpretations, since the nature and composition of any fossil assemblage is influenced by a large variety of paleoenvironmental parameters.

Paleoecological studies are in all likelihood the key to greater understanding of Ordovician ostracode faunas, since environmental adaptation undoubtedly holds the key to morphotype development. Finally, it is worth repeating that the present is the key to the past, or in other words, it is impossible to interpret ostracode paleoecology without an understanding of the ecology of their modern relatives.

PALEOGEOGRAPHY AND PROVINCIALISM

Whatley (1988) reviews the use of ostracodes in paleogeographic reconstructions. An understanding of the biogeography of ostracodes can be used to recognise

important paleoenvironmental transitions (e.g., the shelf-slope transition), the paleolatitude and the prior separation or juxtaposition of continental blocks.

There are several papers that have used the nature and distribution of Ordovician ostracodes to refute or support an existing paleogeographic reconstruction. By demonstrating strong faunal links between the North American and European plates, Schallreuter and Siveter (1985) dispelled the notion that Ordovician ostracodes were endemic to either side of the Iapetus Ocean (McKerrow and Cocks 1976). Because benthic ostracodes lack an easily dispersed pelagic larval stage, Schallreuter and Siveter (1985) suggest that the opposing Ordovician plates were in closer geographic proximity than had been supposed. Vannier *et al.* (1989) use the changing pattern of faunal links between Britain, Baltoscandia and Ibero-Armorica to support Ordovician paleogeographic reconstructions of the Iapetus Ocean, Tornquist's Sea and the Rheic Ocean.

When compared with trilobites or brachiopods, which have frequently been used to solve lower Paleozoic biogeographic problems, use of ostracodes is at rather a crude stage (Schallreuter and Siveter 1985). Further advances will depend on additional taxonomic work, recognition of provincialism, and improved understanding of the mode of life of the palaeocopids.

BIOSTRATIGRAPHY

When compared with the Silurian, where ostracodes have been used for detailed inter- and intra-regional correlations, it is clear that the biostratigraphic potential of Ordovician ostracodes remains largely unrealized.

Faunal turnovers in the Ordovician can be rapid (e.g., Qvale 1980; Jones 1986, 1987), so that some of the easily recognisable ornamented species have limited ranges

and possible biostratigraphic utility. Some workers (e.g., Copeland 1974, 1977b; Berdan and Balanc 1985) have erected ostracode biozones, which have been used regionally to resolve time to the stage level. The main limitations on the use of ostracodes for Ordovician correlations are: (a) correlation between different facies: ostracodes are only easily extracted from some facies such as soft shales, so correlation between different facies is often impossible, (b) sampling intervals are determined by the availability of rock types that can be processed, (c) numbers of specimens: the number of specimens available can vary greatly and is often small, and (d) endemism: although many faunas appear to be less endemic than has been assumed, faunal provincialism can limit long distance correlation.

In summary, correlations using Ordovician ostracodes are generally restricted to areas where ostracodes are easily extracted (e.g., the washed faunas of Anticosti Island or the silicified faunas of northwestern Canada). Given some of the limitations on their use, it is probably unrealistic to expect much more than stage level resolution from ostracode-based correlations. To conclude, Ordovician ostracodes can be biostratigraphically useful, but at present are of most value when used to corroborate age assignments from other shelly faunas.

CHAPTER 5

SUMMARY AND CONCLUDING REMARKS

This chapter is divided into two sections: (a) summary of the research to date, and (b) concluding remarks on Ordovician ostracodes in general.

SUMMARY

Introductory remarks.- This thesis, the first on Ordovician ostracodes from Canada in over thirty years, includes the first detailed descriptions of the faunas of western Newfoundland, together with re-descriptions of faunas from Anticosti Island and the St. Lawrence Lowlands. In addition to documenting these faunas, this thesis also re-interprets their taxonomy, makes a series of paleoenvironmental comments, and summarises the existing knowledge of Ordovician ostracodes.

Taxonomy.- During this study a number of difficulties were encountered in finding, processing, classifying and interpreting the faunas. The taxonomy of a number of species is revised and a number of existing taxa are re-interpreted as synonyms. Because synonymy is common, each species description includes a detailed synonymy list. No new species were established, because: (a) specimens could be assigned to an existing species, or (b) specimens could only be identified at the generic level, because of a lack of well-preserved material and uncertainty over whether the specimens are dimorphs or juveniles.

Paleoecology.- Although faunal composition, abundance and diversity are directly influenced by the paleoenvironment, it is very difficult to develop ostracode-based criteria for the elucidation of Ordovician paleoenvironments. It was not possible to define any recurrent associations between ostracode biofacies and lithofacies, so the paleoenvironmental inferences are based on observations of the nature of the faunas, their taphonomy, and the sedimentology of the studied strata.

Sea-level changes and depth were strong controls on the nature of Ordovician ostracode faunas. In the Lourdes Formation, western Newfoundland and the Ellis Bay Formation, Anticosti Island, marked increases in faunal diversity and the rates of speciation can be directly correlated with transgressive events, that increased the shelf area and the variety of niches available. Similar changes in faunal diversity in response to sea-level changes have also been observed in European Ordovician ostracodes (Vannier *et al.* 1989), Ordovician trilobites (e.g., Shaw and Fortey 1977) and conodonts (e.g., Jaanusson and Bergström 1980).

Water depth, through its control of a variety of interdependent ecological factors, such as light penetration, water temperature, food supply, substrate and turbidity, was also a strong influence on the type of ostracode community present. If the ostracode communities are interpreted in the light of the ecological models of Bretsky and

Lorenz (1970), Eldredge (1974) and Fortey (1984), which relate faunal speciation and diversity in Paleozoic epeiric seas to environmental conditions and particularly environmental stability, it is possible to tentatively recognise the following series of crudely defined, depth-related faunas:

The very shallow, unstable, nearshore environments represented in the Table Point and Lourdes formations, western Newfoundland, and the basal Trenton Group, St. Lawrence Lowlands, either do not contain ostracodes or have a low-diversity fauna of large, robust, smooth ostracodes. Although the number of species is low, each species is often represented by a large number of individuals. Because unstable, nearshore environments are less affected by sudden environmental changes, these faunas have low rates of speciation and a stable community structure.

The faunas with the highest diversity and speciation rates are found in stable, open shelf, carbonate environments, like those represented in the Ellis Bay Formation, Anticosti Island, and the basal Deschambault Formation, St. Lawrence Lowlands. These faunas are made up of a wide variety of benthic ornamented forms such as eurychilinids and tetradellids. Because stable, open shelf environments are often adversely affected by sudden environmental changes, these faunas have high speciation rates and their community structure frequently changes.

The character of the faunas change with increasing depth. Outer shelf deposits, like the Vauréal formation, Anticosti Island contain a low-diversity, low-abundance fauna that mainly consists of binodicopids and smooth elongate ostracodes. Outer shelf faunas have low speciation rates and a stable community structure. As depth increases and the shelf-slope transition is crossed (e.g., the boundary between the Trenton and Utica groups in the Lowlands), faunal diversity and abundance diminish rapidly, and *in situ* ostracodes disappear altogether.

Although these bathymetric communities are only crudely defined, similar depth-related communities have been used to explain the distribution of Ordovician trilobites

(Fortey 1975) and European Ordovician ostracodes (Vannier *et al.* 1989). In this analysis, the appearances of new taxa are taken as speciation events, that are triggered by environmental changes like transgressive sea-level rises. It is possible however, that these faunal changes reflect faunal migrations in response to environmental shifts rather than evolutionary novelty (e.g., Fortey 1984).

CONCLUDING REMARKS

This section includes a series of concluding remarks on Ordovician ostracodes, and a number of recommendations to clarify their taxonomy and improve their paleoenvironmental and biostratigraphic usefulness. Before making specific comments on the taxonomy, paleoecology and biostratigraphy of Ordovician ostracodes, it should be noted that these ostracodes are in general, poorly known. There are large areas of uncertainty and most aspects of the faunas require further research.

Taxonomy.- Ordovician ostracode taxonomy is complex and difficult to use. Many taxa are oversplit and synonyms are common. There is no real consensus on suprageneric classification and only limited taxonomic stability has been achieved. Kaesler (1983) considers the wealth of names produced by oversplitting to be counterproductive, because: (a) it hinders communication about similar taxa, (b) it can prevent recognition of intraspecific variation, and (c) taxa with different names are often considered to be different by definition, and are not subject to comparison. Because of uncertainty about the extent of eco-phenotypic, genotypic and intraspecific variation in fossil and recent Ostracoda, current concepts of fossil species are questionable and open to re-interpretation. Great care should therefore be taken in establishing new species. There is little point in assigning numerous specific or

generic names to a range of eco-morphotypes, that may in reality belong to one species. At higher taxonomic levels there are already enough taxa (Kaesler 1983). There is no useful purpose in either establishing new genera, when old ones can be emended, or in inflating the status of taxa to accommodate further subdivisions of existing taxa.

Ordovician ostracode taxonomy is so complex, that it is easy to become entangled in intricacies, making it impossible to get an overview of the fauna. The following steps would help to simplify the existing taxonomy and make it more valuable as a method of communication: (a) new taxa should only be established when absolutely necessary, and any new taxon should differ significantly from all existing taxa, (b) all published studies should be based on large faunas, because it is essential to know the dimorphic and ontogenetic character of any proposed taxon, (c) more rigorous synonymy lists need to be included in all faunal descriptions, because synonyms are more common than the wealth of names in the literature suggests, (d) some creative lumping is needed, because there is little room for morphological variation in most ostracode species; current genera could be re-termed species, to allow a more reasonable degree of intraspecific variation, and (e) some taxonomic deflation is needed, so that higher level taxonomic divisions reflect significant morphological differences; at present there is more morphological variation in a single genus of many organisms than in most ostracode suborders.

Before concluding, several general comments and suggestions should be made on North American Ordovician ostracode faunas. These faunas are poorly known, and further painstaking and time-consuming taxonomic research is needed to establish their character. There are many undiscovered faunas, and several existing faunas still need to be documented. In addition, the taxonomy of a number of key faunas is out-of-date and in need of revision. Future taxonomic studies should be approached from an ecological perspective, which recognises the extent to which morphology varies with

the environment. During taxonomic investigations, recognition of synonyms and creative lumping should be top priorities, so that the resulting taxonomy can become a more reliable means of communicating information.

The location and status of much North American type material is uncertain. An onerous, but useful task would be to publish a register of the locations of the types that are available. In addition, comparisons would be easier if all the type material was housed in a single repository. At present, little work is being done on North American Ordovician ostracodes, and since it takes many years to build an expertise, it is likely that these faunas will continue to be neglected. In order to find out more about these faunas, a small taxonomic working group is needed. This group should be large enough to encompass a diverse series of view points, stimulating constructive discussion of the faunas.

Paleoecology.- Ordovician ostracodes had very similar lifestyles to their modern relatives (Siveter 1988). They lived in relatively shallow, marine habitats, on the open shelf or at the shelf-slope transition. As far as is known, all Ordovician ostracodes were benthic (Schallreuter and Siveter 1985). On the sea-floor, these ostracodes lived as crawlers, short distance swimmers, or perhaps even as burrowers (Siveter 1984, 1989). Benthic ostracodes are opportunistic colonizers, but because they have no known larval stage (Elofson 1941), deep water is a formidable barrier to their dispersal (Schallreuter and Siveter 1985). Salinity, substrate and depth-related factors, such as bottom-water temperatures were the most important controls on the overall distribution of Ordovician ostracodes (Schallreuter and Siveter 1985).

Although we have a general knowledge of the paleoecology of Ordovician ostracodes, there are large areas of uncertainty, and detailed knowledge of the paleoecology of the faunas is limited. In order to improve current knowledge, follow-up research is suggested in the following areas: (a) the extent to which faunas are

facies controlled, (b) the geographical ranges of species, and (c) the mode of life and autecology of palaeocopid species. This kind of research will take meticulous, time-consuming work, and should include detailed logs, rigorous paleoenvironmental interpretations, and extensive sampling.

Ostracodes can be good paleoenvironmental indicators, particularly in post-Paleozoic rocks, which contain ostracodes that are readily comparable with modern forms. Because the vast majority of Ordovician ostracodes have no living representatives, use of these ostracodes as paleoenvironmental indicators is more difficult, and must rely on information synthesised from a number of sources, including taphonomy, functional morphology and associations between faunas and paleoenvironments. Recognition of recurrent associations between taxa, morphotypes, or faunal assemblages and paleoenvironments could for example, establish the type of ostracode communities that are characteristic of various paleoenvironmental settings.

Establishing relationships between taxa or morphotypes and paleoenvironments is not easy. It requires examination of a wide variety of faunas, synthesis of paleoenvironmental observations, and the development and testing of a variety of simple ratios, indices and graphical plots that relate the nature of the ostracode fauna to the paleoenvironment. During the current study, a series of crude depth-related assemblages were recognised. If quantitative or qualitative recurrent associations between assemblages and paleoenvironment can be recognised in the future, it may be possible to recognise a series of depth-related assemblages along an onshore-offshore coenocline.

Biostratigraphy.- Effective use of Ordovician ostracodes as biostratigraphic indicators, depends on their ability to cross facies and provincial boundaries. A few species, e.g., *Tetradella quadrilirata*, are very wide ranging and have obvious potential for correlating Ordovician shelf sediments. Many other species cannot be

used for inter- or intra-regional correlation, because they are locally endemic, occurring in some areas and not in others. At present, it is not possible to make more than crude correlations, because the faunas are not well enough known. The stratigraphical and geographical ranges of nearly all species are, for example, unknown or uncertain. More basic research is needed. Future work will be laborious and should include ascertaining the geographical and stratigraphical ranges of species, through reviews of previous work, and detailed logging and sampling of new sections.

CHAPTER 6

TAXONOMIC DESCRIPTIONS

METHODS AND MATERIALS

Introduction.- The ostracode collections described here are from two sources. Those from western Newfoundland and Anticosti Island are from samples collected and prepared by the author while those from the St. Lawrence Lowlands are from samples collected by the author and from the Carter Collection. The Carter Collection, which was borrowed from the Redpath Museum, McGill University, Montréal, consists of several hundred labelled glass vials containing the ostracodes that Carter (1957) described in his thesis.

The following samples were collected by the author: T-1 to T-11 and L-1 to L-30 from the Table Point and Long Point areas of western Newfoundland; A-1 to A-16 from Anticosti Island and S-1 to S-5 from the Lowlands. Samples S-6 to S-24 were

prepared by Carter (1957), the resulting ostracodes now form part of the Carter Collection. Carter's (1957) samples were re-numbered to conform with the sample numbering system adopted here.

Sampling procedures.- All the samples from western Newfoundland and Anticosti Island and some from the St. Lawrence Lowlands are tied to measured sections (given in Appendix 3). Carter's (1957) samples are from localities throughout the Lowlands; many of these localities are now inaccessible because of quarry infilling, hydro-dams, new roads, etc.

Although the type of ostracode preparation method to be used was the main criterion influencing sample selection, whenever possible, samples were taken at roughly even intervals. Sample size was generally about 2 kg, but where good washable material was available, samples were considerably larger (over 20 kg). Samples containing visible ostracodes for vibra-tool preparation were carefully wrapped in tissue paper to prevent damage during transit. All samples were collected from the narrowest possible stratigraphical interval in an attempt to minimise the impact of time-averaging.

Preparation techniques.- The various techniques used to prepare the samples collected during this study are outlined below:

WASHED SAMPLES.- Samples for washing should be soft, susceptible to break-down and ostracode release during boiling or wet sieving. The lithologies best suited for washing are friable siltstones or shales and any weathered material. After washing and oven drying the residues were sieved into 63 μ, 125 μ, 250 μ, 500 μ, and 800 μ fractions; ostracodes were then picked and sorted onto faunal slides using a Carl Zeiss binocular microscope.

VIBRA-TOOL PREPARATION.- The best method to extract calcified ostracodes from

indurate limestones, is with a vibra-tool (in this study, a Dremel vibra-tool with a fine engraving point was used) and fine-needles. To achieve success it is important that ostracodes are found in the field, before sampling is undertaken. In the laboratory, samples, which should be large enough to hold firmly, were examined with a binocular microscope and specimens for extraction were marked with a coloured pencil. Each specimen selected was carefully cleaned of any obscuring matrix with a wet brush, fine-needle or vibra-tool and was then removed from the rock mass by digging a groove around the specimen with the vibra-tool until it popped out. Prepared specimens were stored in small plastic vials. Vibra-tool work is extremely time-consuming; many specimens are broken in the process and other specimens pop-out unpredictably and can be lost. The number of specimens recorded from vibra-tool prepared samples only reflects the number of specimens that were prepared; the total number of ostracodes in the sample may be an order of magnitude larger.

ACID PREPARATION.- Two types of acid preparation were tried, using hydrochloric and hydrofluoric acids. Both preparation techniques rely on differences in chemistry between the containing rock and the enclosed ostracodes, that allow the ostracodes to be released during sample break-down.

Hydrochloric acid: All samples of indurate limestone and calcareous sandstones were checked for silicification by dissolving about 0.25 kg of the sample in dilute (10%) hydrochloric acid. The resulting residues were washed and examined, but none of the samples yielded silicified ostracodes. See Jones (1986, pp. 16-18) for detailed description of preparation techniques for silicified ostracodes.

Hydrofluoric acid: Cherts from the Table Head Group and shaly limestones from the Long Point Group were etched with 35% hydrofluoric acid using the technique described by Schallreuter (1982a), in which the silica is dissolved, releasing ostracode pseudomorphs of amorphic calcium fluoride. Although several of the samples broke down during hydrofluoric acid preparation, none yielded ostracodes.

Photography.- Apart from the large leperditiids which were photographed with a Wild M400 light microscope, all the ostracodes were mounted on aluminum stubs or rivets, splatter coated with gold and photographed at 15 KV with a Hitachi S570 scanning electron microscope. Saliva was found to be the best mounting medium. When charging occurred, specimens were re-mounted and re-coated with gold to reduce static build up.

Drawings.- Camera lucida drawings were made of the entire fauna; all the drawings are at the same scale and are included so that the relative sizes of the various species can be easily seen.

Curation.- The author's ostracode collection is stored in the Department of Earth Sciences, Memorial University of Newfoundland, as thesis collection W-18. The Carter Collection has been returned to the Redpath Museum, Montréal, and can be viewed there on request.

TAXONOMIC DESCRIPTIONS, AN INTRODUCTION

Introduction.- The taxonomic descriptions given here are literature based and no type material was examined. Much of the type material is old, poorly illustrated and in some cases lost; further research should emphasise re-examination and re-illustration of type material. Many Ordovician ostracode species were established before sexual dimorphism, ecdysis and ecophenotypic variation were recognised and as a consequence some species are based on dimorphs, juveniles or ecophenotypes. Type localities need to be re-sampled where possible, so that the range of variability and population structure of each species can be soundly established. Because this thesis

attempts to describe and illustrate the entire fauna available, some species are only represented by a few specimens.

Terminology and abbreviations.- The descriptive terminology used here is essentially that of Scott *in* Moore (1961, pp. Q21-Q36), which is itself largely based on the work of Kesling (1951) and Jaanusson (1957). The terms used to describe palaeocopid ostracodes are summarised in Fig. 20a. This author follows Jaanusson's (1957) definitions of tecnomorph and heteromorph: "in dimorphic species, specimens of juveniles and the adults which resemble them, are termed tecnomorphs, while specimens of the presumed females, which have characteristics not occurring in the tecnomorphs are termed heteromorphs". Throughout the descriptions, pl. and fig. are used as abbreviations for plate and figure. The terms LV and HV refer to the greatest length and height of the ostracode (Fig. 20b), while LD and HD refer to the greatest length and height of the domicilium.

Description and measurements.- The taxonomic descriptions are laid out in a standard manner; some comments on the various headings used in the taxonomic section are made below.

SYNONYMY.- The synonymy lists are not lists of the taxon's occurence, but are lists of subjectively examined illustrations that the author considers synonymous with the taxon being described. Reports which do not include illustrations are only included for good reason, i.e., when the information improves taxonomic understanding or where the report refers to an illustration cited elsewhere in the list. Key references, which usually result from the study of new faunas, have their dates in **bold**; a number of references simply repeat illustrations from previous work, but are included for completeness. Because they are valuable sources of information, in a field with limited literature, several unpublished theses are referred to.

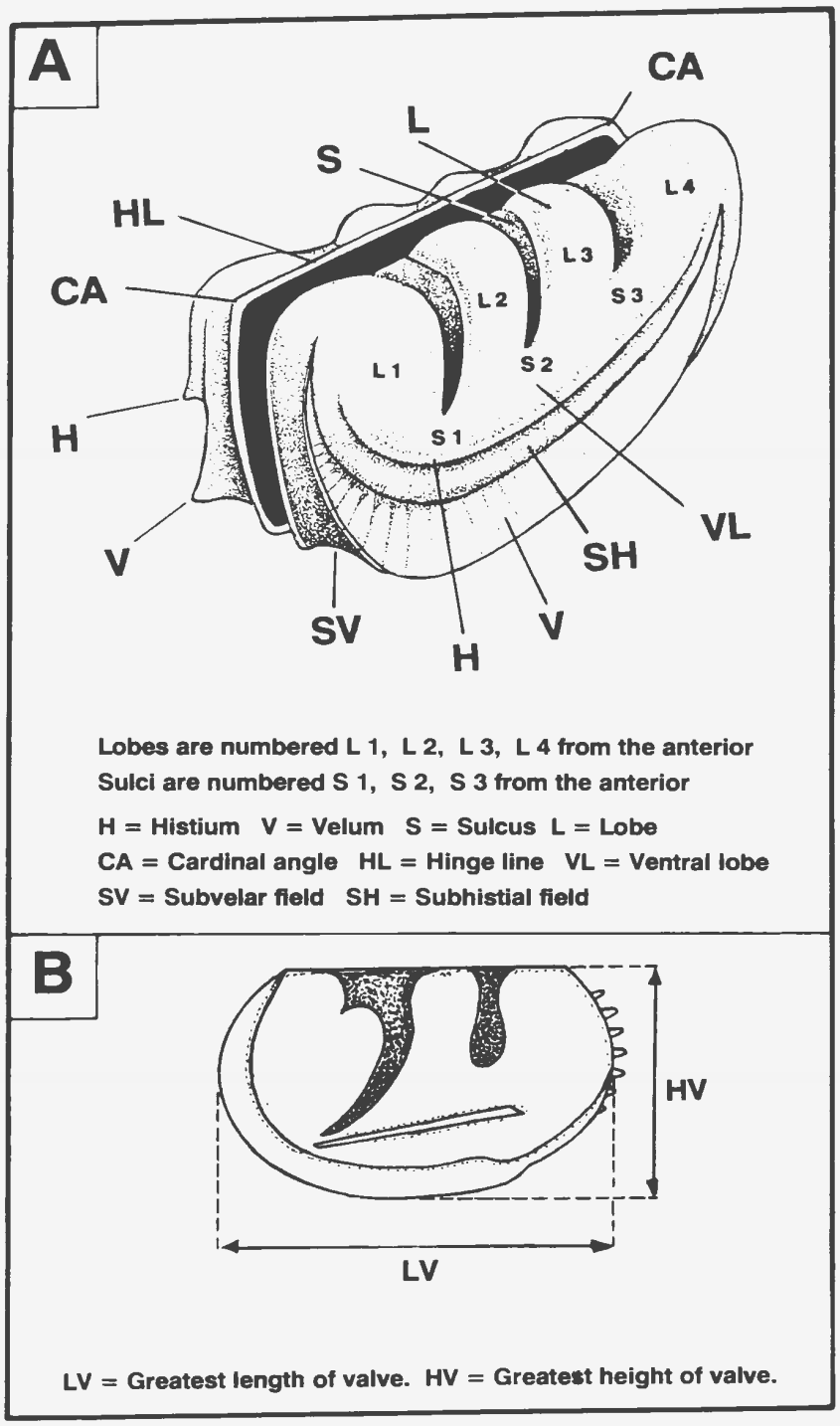


Fig. 20a. Terminology used to describe palaeocopid ostracodes, (original drawing from Vannier 1986b).

Fig. 20b. Diagram showing LV and HV of specimens, (original drawing from Jones 1986).

DESCRIPTION.- Descriptions were kept short, and specimens are described in the following order: shape, outline, margins, dimorphic features and lateral surface. Unless otherwise mentioned, all descriptions are of lateral views.

MEASUREMENTS.- For all species, the greatest length (LV) and greatest height (HV) were measured. In the case of species represented by less than thirty specimens, the LV and HV of a selection of the larger and presumed adult specimens are given. In the case of species represented by more than thirty specimens, size dispersion diagrams have been plotted. Because specimens of the same size plot at the same point, the number of data points in some of the size dispersion diagrams is less than the number of specimens actually measured. Measurements of the larger leperditiid ostracodes were made with callipers and are given to the nearest 0.5 mm, while measurements of the smaller ostracodes were made using a Carl Zeiss binocular microscope with a calibrated ocular and are given to the nearest 25 μ.

MATERIAL.- The number of valves and carapaces examined are given and comments are made on the nature of specimen preservation. Use of material from the Carter Collection is acknowledged here.

OCCURRENCE.- Lists the sample(s) and lithostratigraphic horizon(s), in which the species occurs.

TAXONOMIC DESCRIPTIONS

Phylum, Subphylum or Superclass CRUSTACEA Pennant 1777

Diagnosis.- See Abele (1982) and Schram (1986).

Remarks.- Strong differences of opinion exist on the classification of the Arthropoda and the taxonomic position of the Crustacea. Because the position of the Crustacea does not affect this study, this writer follows Bowman and Abele (1982), in offering the reader the option of selecting the hierarchical category he or she prefers for the Crustacea. See McKenzie (1989) for an up-to-date review of the crustaceans.

Subclass OSTRACODA Latreille 1802

(*nom. correct.* Latreille 1806)

Diagnosis.- See Sylvester-Bradley *in* Moore (1961, p. Q100), Maddocks (1982, pp. 221-239) and Schram (1986, pp. 399-423).

Remarks.- Despite nearly a century of speculation, the relationship between the Ostracoda and other Crustacea remains uncertain (Maddocks 1982, p. 221). This gap in understanding has been expressed taxonomically, by ranking the Ostracoda as a major subdivision (either a class or subclass) of the Crustacea. The historical development of ostracode taxonomy has been outlined by a number of authors, including Scott *in* Moore (1961, pp. Q74-Q78) and Schram (1986, p. 399) and is not repeated here.

Ostracode taxonomy has often been characterised by disagreement. It is rare, for example, for any two taxonomists to agree on a suprageneric classification scheme. This disorder is, in part, related to the different approaches adopted by biologists (soft parts) and paleontologists (hard parts) to ostracode taxonomy, and to the tendency to oversplit and inflate the status of taxa. Taxa which started as genera or subfamilies have, in the course of a few generations become superfamilies or suborders. This taxonomic inflation is usually justified by the need to create space for the further subdivision of existing taxa.

Although the classification scheme laid out in the *Treatise* (Moore 1961) is out-of-date and presently undergoing revision, it remains the single most important taxonomic source available and as such, forms the basis for the classification adopted here. Modifications to the *Treatise* classification scheme, reflecting the recent work of Warshauer and Berdan (1982), Berdan (1988) and Vannier *et al.* (1989) are made where appropriate. Publication of the new *Treatise* (expected in 1992) is unlikely to resolve many of the differences of opinion among ostracode workers, but should clarify and stabilize the existing taxonomy.

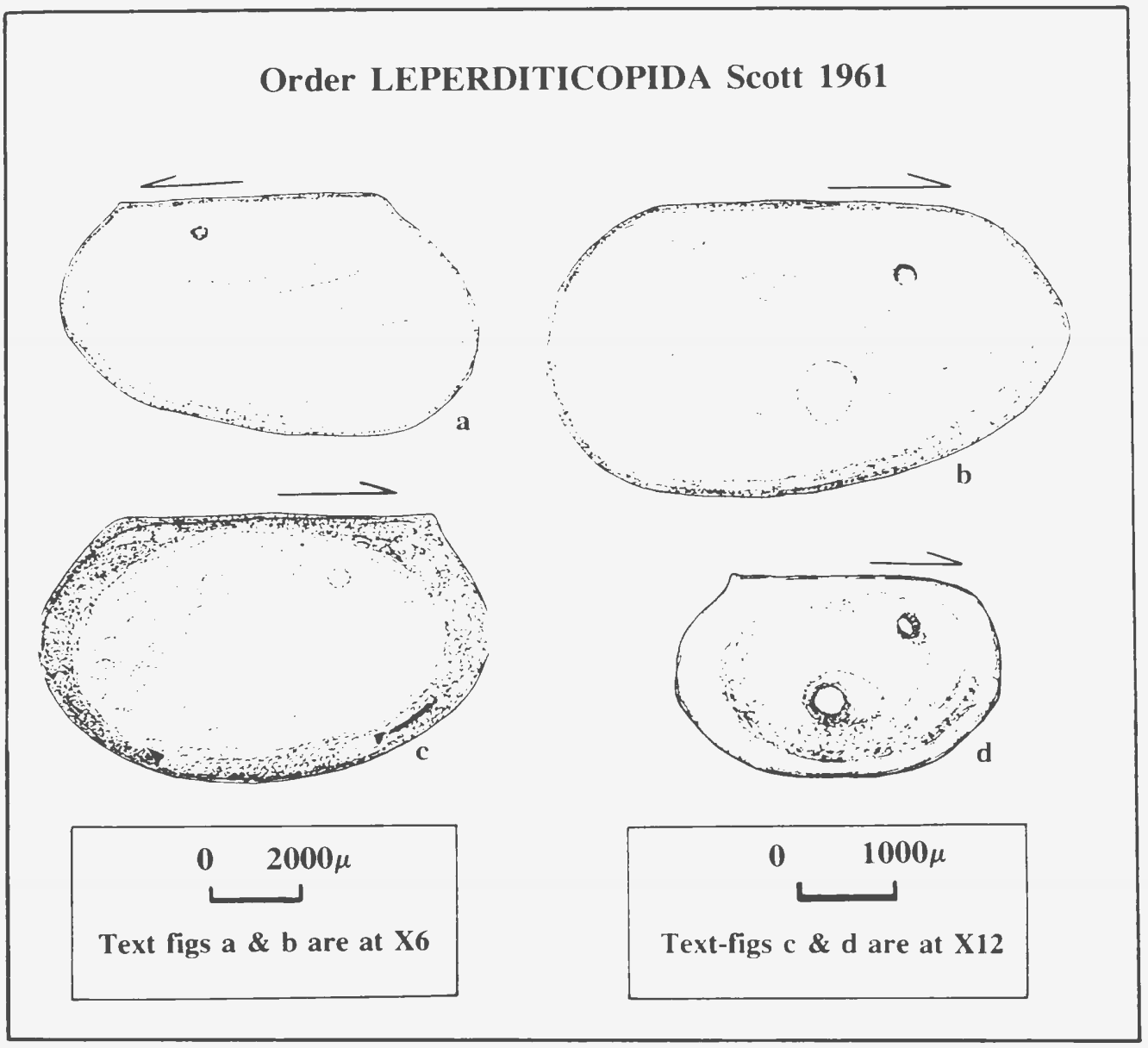
Although the International Commission on Zoological Nomenclature (I.C.Z.N.) recommends (Recommendation 29A) that names of superfamilies should end with "*-oidea*", the current convention amongst ostracode workers is to use "*-acea*" as the superfamilial ending. This practice is followed here.

Order LEPERDITICOPIDA Scott 1961

Diagnosis.- See Scott *in* Moore (1961, pp. Q103-Q105) and Berdan (1984, p. J.18).

Remarks.- Leperditicopids are universally recognised as unique amongst ostracodes; their large size and heavily calcified shells readily distinguish them from other ostracodes. Apart from being several orders of magnitude larger than any other

Text-fig. 1



a. *Eoleperditia fabulites* (Conrad 1843)
Lourdes Formation, western Newfoundland, (L-7).

b. *Eoleperditia fabulites* (Conrad 1843)
Lourdes Formation, western Newfoundland, (L-7).

c. *Bivia bivia* (White 1874)
Table Point Formation, western Newfoundland, (T-3).

d *Isochilina* sp.
Beekmantown Group, St. Lawrence Lowlands, (S-9).

ostracodes, the leperditicopids are inequivalved, straight hinged and have distinctive muscle scar patterns. Although leperditicopids have been reported from the Cambrian, they are most common in Ordovician to Devonian strata (Berdan 1984). The leperditicopids have been subdivided into two families, the distinctly inequivalved leperditiids and the subequivalved isochilinids (Berdan 1984, p. J18). In this writer's opinion, leperditicopid taxonomy is confused and difficult to use, because leperditicope taxa are oversplit at all levels. The confusion engendered by oversplitting has been compounded by the use of subjective classificatory criteria that are only recognisable in exceptionally preserved specimens. Unravelling and revising leperditicope taxonomy would involve a re-examination of type collections and a re-collection of type localities; a huge task that is well beyond the scope of this thesis. Berdan's recent (1984) review of the leperditicopids is the best source of further information on the group.

Family LEPERDITIIDAE Jones 1856

Diagnosis.- See Scott *in* Moore (1961, pp. Q105-106), Swain (1957, p. 545) and Berdan (1984, pp. J4, J18).

Remarks.- The Family Leperditiidae was recently re-defined by Berdan (1984, p. J18) to encompass those leperditicopid genera that are distinctly inequivalved and have a sinuous contact margin in ventral view. In the field, leperditiids tend to occur as large, low diversity assemblages that contain dissociated valves of several moult stages. Leperditiids are most often found in shallow subtidal to intertidal micritic limestones (Berdan 1984), and are thought to have lived as scavengers or deposit feeders (Belak 1977). Because facies control of leperditiids is widespread (Berdan 1969, 1981), they have been neglected as biostratigraphic indicators. They are however locally useful

for Ordovician correlations (Berdan, 1984, p. J18), and have potential for regional correlations in the Silurian (Copeland, 1976). Abushik (1966) reviews the various features used to orientate leperditiids.

Genus *Eoleperditia* Swartz 1949

Type species.- *Cytherina fabulites* Conrad 1843

Diagnosis.- See Swartz (1949, pp. 317-318), Scott (1951, pp. 321-326) and Scott *in* Moore (1961, p. Q106).

Occurrence.- Known from the Middle Ordovician worldwide, but best known from central and eastern North America, (Scott *in* Moore 1961, p. Q106).

Eoleperditia fabulites (Conrad 1843)

Pl. 1, fig. 1; text-figs. 1a-b.

Synonymy.-

1843 *Cytherina fabulites* Conrad, p. 332, (not figured).

1858a *Leperditia canadensis* var. *josephiana* Jones, pp. 94-95, pl. 11, fig. 16.

1890 *Leperditia fabulites* (Conrad); Ulrich, pp. 173-174, pl. 11, figs. 1a-d.

1894 *Leperditia fabulites* (Conrad); Ulrich, p. 634, pl. 43, figs. 10-14.

1923a *Leperditia fabulites* (Conrad); Ulrich and Bassler, pp. 294-295, fig. 13, nos. 1-5.

1931 *Leperditia fabulites* (Conrad); Harris, p. 87. pl. 10, figs. 1-2.

1944 *Leperditia fabulites* (Conrad); Shimer and Shrock, p. 664, pl. 280, figs. 1-4.

1948 *Leperditia fabulites* (Conrad); Wright, pl. 1, figs. 1-5, (unpublished).

1949 *Eoleperditia fabulites* (Conrad); Swartz, pp. 318-319, pl. 66, figs. 1-10.

1951 *Eoleperditia fabulites* (Conrad); Scott, pp. 321-326, pl. 51, figs. 1-5.

1952 *Leperditia fabulites* (Conrad); Moore, Lalicker and Fischer, p. 525, fig. 14.2, nos. 3a-b.

1957 *Eoleperditia fabulites* (Conrad); Carter, pp. 49-51, pl. 1, figs. 1a-c, (unpublished).

1957 *Eoleperditia fabulites* (Conrad); Swain, pp. 545-546, pl. 59, figs. 1, 3, 5, 8.

1957 *Eoleperditia fabulites* (Conrad); Harris, pp. 129-130, pl. 1, figs. 1a-b.

1961 *Eoleperditia fabulites* (Conrad); Scott *in* Moore, p. Q106, figs. 42.2a-c.

1972 *Eoleperditia fabulites* (Conrad); Bolton and Copeland, pl. A, figs. 13, 19-20.

1974 *Eoleperditia fabulites* (Conrad); Copeland, p. 14, pl. 5, figs. 6-9; text-figs. 5.1-5.4.

1978 *Eoleperditia fabulites* (Conrad); Copeland, pl. 1, fig. 9.

1984 *Eoleperditia fabulites* (Conrad); Berdan, pp. J18-J20, pl. 1, figs. 1-12.

Holotype.- Because specimens of the holotype *Cytherina fabulites* Conrad 1843 are presumed lost, Berdan (1984, p. J18-J199) suggested that either suitable topotype material be found or that the specimen of *Leperditia fabulites* illustrated by Ulrich (1890, pl. 11, figs. 1a-d) be designated the neotype. In the meantime, Berdan (1984, p. J18) used the holotype and paratypes of the junior synonym *Leperditia canadensis* var. *josephiana* Jones 1858 as her type material. Berdan (1984, pp. J18-J20) discusses the type material of *Eoleperditia fabulites* in more detail.

Diagnosis.- See Swartz (1949, pp. 318-319), Scott (1951, pp. 321-326) and Berdan (1984, pp. J18-J20).

Description.- Valves subovate and slightly postplete. HV posterior of mid-length, LV at about mid-height, WV below mid-height. Dorsal margin straight, ventral margin gently curved; anterior and posterior margins evenly rounded. Anterior cardinal angle about 120°, posterior cardinal angle about 130°. Eyespot weak to

indistinguishable. Adductor muscle scar ovate, individual stigmata not visible. Shell surface smooth to finely granulose. No marginal brims or stop-pits observed. Several attempts were made to prepare specimens so that valve interiors could be examined; unfortunately this met with little success and only produced badly broken valves.

Measurements.- LV 17.0 mm, 12.0 mm, 11.5 mm, 11.0 mm, 10.5 mm.
HV 11.0 mm, 8.0 mm, 7.0 mm, 7.0 mm, 7.0 mm.

Remarks.- Further discussion of *Eoleperditia fabulites* can be found in Berdan (1984, pp. J18-J20). A number of other species are probably synonymous with *Eoleperditia fabulites*, but unless the types, type collections and type localities of these species are re-examined, they cannot be described as synonyms with any degree of confidence. In addition, more and better preserved material is needed from the present localities, so that the degree of intraspecific variation can be assessed. Schuchert and Dunbar (1934), Sullivan (1940), Corkin (1965) and Bergström *et al.* (1974) have all reported, but not figured, leperditiids from the Lourdes Formation; their taxa are almost certainly synonymous with the specimens termed *Eoleperditia fabulites* here.

Material.- Ten calcified valves; material consists of five somewhat flattened valves from (L-7) and five valves from the Cater Collection, (S-20). All the specimens have their original shell material preserved.

Occurrence.- Black Duck Member (L-7), Lourdes Formation, western Newfoundland and Leray Formation (S-20), St. Raymond map-area, St. Lawrence Lowlands.

Genus *Bivia* Berdan 1976

Type species.- *Leperditia bivia* White 1874

Diagnosis.- See Berdan (1976, pp. 44-46).

Remarks.- Berdan (1976) cited differences in the number of stop-pits, when she split *Bivia* from the otherwise similar genus *Eoleperditia* Swartz 1949. Use of difficult to

recognise and variable characters like the number of stop-pits as classificatory criteria has, in this author's opinion, increased the complexity of leperditiid taxonomy. A thorough revision of leperditiid genera is needed, so that genera are less narrowly defined and allow a reasonable degree of intraspecific variation.

Occurrence.- Known from the Middle to Upper Ordovician of North America, (Berdan 1976, p. 46).

***Bivia bivia* (White 1874)**

Pl. 1, fig. 2; pl. 2, figs. 1-2; text-fig. 1c.

Synonymy.- 1874 *Leperditia bivia* White, p. 11, (not figured).
1877 *Leperditia bivia* White; White, pp. 58-59, pl. 3, figs. 7a-d.
?1928 *Leperditia catheyensis* Kirk, pp. 416-417, figs. 6a-e.
?1957 *Eoleperditia inflativentralis* Harris, pp. 130-131, pl. 1, figs. 2a-b.
?1957 *Eoleperditia magna* Harris, pp. 131-132, pl. 1, figs. 3a-b.
?1957 *Eoleperditia mediumbonata* Harris, pp. 132-133, pl. 1, figs. 4a-b.
?1957 *Eoleperditia mediumbonata* subsp. *debilis* Harris, p. 133, pl. 1, figs. 6a-b.
?1957 *Eoleperditia subcarinata* Harris, p. 137, pl. 1, figs. 11a-b.
1963 *Eoleperditia bivia* (White); Berdan *in* Whittington and Kindle, p. 747, (not figured).
1970 *Eoleperditia bivia* (White); Berdan *in* Ross, pp. 8-9, 12, 19, 27, 40, (not figured).
1974 *Eoleperditia bivia* (White); Copeland, p. 15, pl. 9, figs. 18-20.
1976 *Bivia bivia* (White); Berdan, p. 42, pp. 46-50, pl. 1, figs. 1-7; pl. 2, figs. 1-6; pl. 3, figs. 1-9.
?1976 *Bivia floweri* Berdan, pp. 50-52, pl. 4, figs. 1-5; pl. 5, figs. 1-3.

?1976 *Bivia duncanae* Berdan, pp. 54-56, pl. 5, fig. 4; pl. 6, figs. 1-8.

?1976 *Bivia dubia* Berdan, pp. 56-58, pl. 7, figs. 1-7.

?1984 *Bivia tumidula* (Ulrich); Berdan, pp. J21-J22, pl. 3, figs. 1-8; pl. 4, figs. 1-6.

?1984 *Bivia linneyi* (Ulrich); Berdan, pp. J22-J24, pl. 5, figs. 1-7.

?1984 *Bivia frankfortensis* (Ulrich); Berdan, pp. J24-J25, pl. 6, figs. 1-17.

1987 *Bivia bivia* (White); Berdan *in* Ross and James, p. 95, (not figured).

?1987 *Bivia* sp. Berdan *in* Ross and James, p. 95, (not figured).

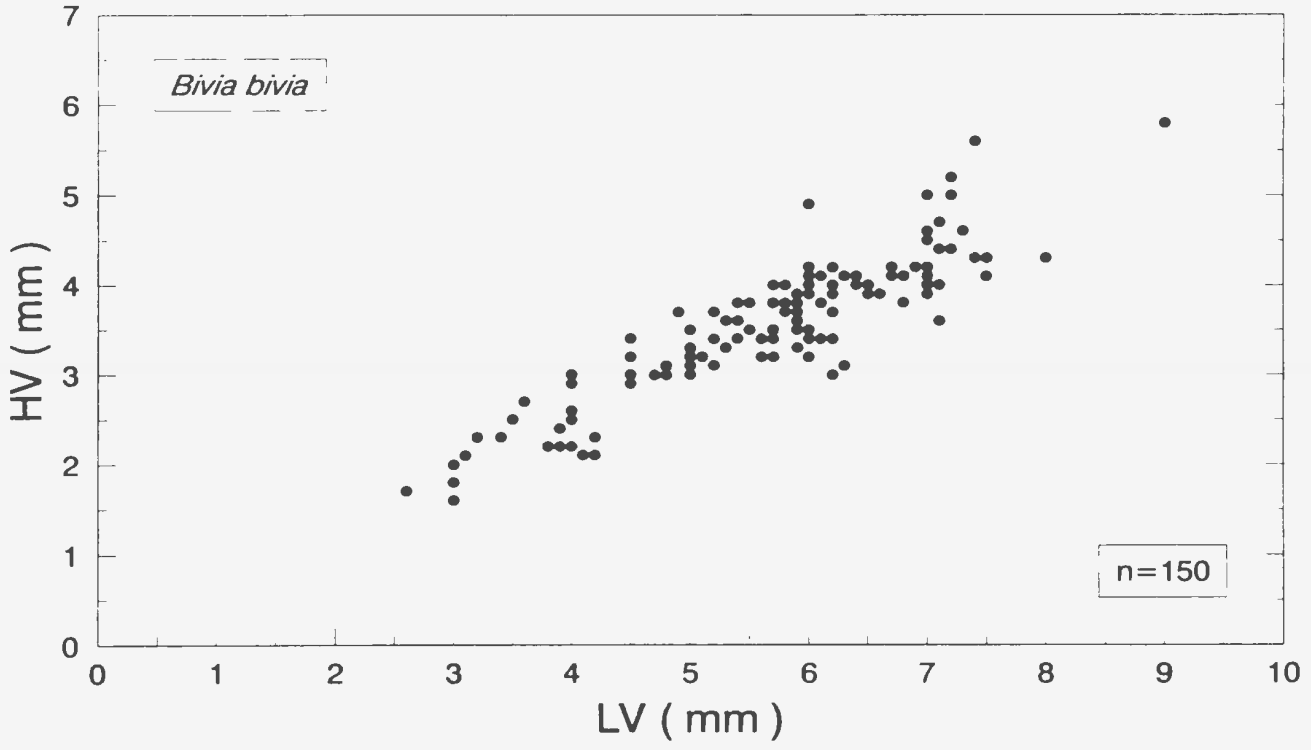
?1987 *Bivia* sp. cf. *Bivia duncanae* Berdan; Berdan *in* Ross and James, p. 95, (not figured).

Holotype.- When White (1874, p. 11) first described *Leperditia bivia* he didn't illustrate it or designate a holotype. Berdan (1976, pp. 46-50) re-described *Bivia bivia* (White 1874) and designated a lectotype (Berdan 1976, pl. 1, figs. 5-7) and paralectoypes (Berdan 1976, figs. 1-4) from White's original syntypes. See Berdan (1976, pp. 48-50) for further discussion of the type material.

Diagnosis.- See Berdan (1976, pp. 46-50).

Description.- Valves subovate and amplete to slightly postplete. HV posterior of mid-length, LV at about mid-height, WV below mid-height. Dorsal margin straight, anterior margin more sharply rounded than posterior margin, ventral margin gently curved. Cardinal angles sharp; anterior cardinal angle about 110°, posterior cardinal angle about 120°. Anterior and posterior margins flattened into a marginal brim, which is best developed in right valves. Flattened margins on right valves end ventrally at distinctive stop-pits, one on each side of the ventral lappet. Right and left valves evenly inflated. Small eye tubercle developed in some specimens. Shell surface smooth. No dimorphism observed.

Measurements.- The specimens of *Bivia bivia* exhibit continuous size variation (Text-fig. 2). No instar patterns can be recognised.



Text-fig. 2. Size dispersion diagram of *Bivia bivia* (White 1874) from samples T-3 and T-7.

Remarks.- Taxa like *Bivia floweri*, *Bivia duncanae*, *Bivia dubia*, *Bivia tumidula*, *Bivia linneyi* and *Bivia frankfortensis* as figured by Berdan (1976 and 1984) are tentatively included in synonymy with *Bivia bivia*. In this author's opinion, the differences between these taxa reflect intraspecific rather than specific variation. A number of the species of *Isochilina* Jones 1858, *Teichochilina* Swartz 1949 and *Parabriartina* Berdan 1984 that are figured by Swain (1957) and Berdan (1984) are similar to *Bivia bivia*.

Material.- At least several hundred dissociated valves of several moult stages scattered on bedding plane surfaces; all the valves have their original shell material preserved.

Occurrence.- Occurs throughout the Table Point Formation (T-1, T-2, T-4, T-5, T-6, T-9) western Newfoundland, but particularly common on bedding planes at sample localities (T-3, T-7).

Family ISOCHILINIDAE Swartz 1949

Diagnosis.- See Scott *in* Moore (1961, p. Q108) and Berdan (1984, pp. J4, J18).

Remarks.- The family Isochilinidae was recently re-defined by Berdan (1984, p. J18) to encompass those leperditicopid genera which are subequivalved and have a straight contact margin in ventral view.

Genus *Isochilina* Jones 1858

Type species.- *Leperditia (Isochilina) ottawa* Jones 1858

Diagnosis.- See Jones (1858b, p. 248), Scott *in* Moore (1961, p. Q109) and Berdan (1984, p. J25).

Occurrence.- Known from the Lower Ordovician to Middle Devonian of North America, (Scott *in* Moore 1961, p. Q109).

Isochilina **sp.**

Pl. 2, fig. 3; text-fig. 1d.

Synonymy.- **1957** *Isochilina conicalis* Carter, pp. 65-67, pl. 2, figs. 3a-e, (unpublished).

Description.- Valves subelliptical and dorsally truncate. HV slightly posterior of mid-length, LV at about mid-height, WV below mid-height. Dorsal margin straight, anterior and posterior margins evenly rounded, ventral margin very gently curved. Straight hinge line with sharp cardinal angles; anterior cardinal angle about 120°, posterior cardinal angle about 130°. Narrow flattened marginal brim extends around entire free margin. Median to ventromedian portion of valve extends outwards into a

distinctive, posteriorly projecting, subconical process. Prominent anterodorsal eye tubercle. Hinge and locking pits not seen. Surface smooth.

Measurements.- LV 3350 μ, 3300 μ, 3125 μ, 2875 μ, 2475 μ, 2150 μ.
HV 2175 μ, 2100 μ, 2025 μ, 1800 μ, 1625 μ, 1375 μ.

Remarks.- Although *Isochilina cristata* (Whitfield 1889) and *Isochilina amiana insignis* Ulrich 1890 are similar to the present taxon, it is not possible to confirm their synonymy, because illustrations of these two species (Jones 1890b, pl. 1, fig. 8.) and (Ulrich 1890, pl. 11, fig. 13) are poor. *Eoleperditia? perplexa* Harris 1957 (pl. 1, figs. 8a-b), *Ceratoleperditia arbucklensis* Harris 1964 (figs. 1a-c) and *Ceratoleperditia kentuckyensis* (Ulrich 1890) as figured by Berdan (1984, pl. 7, figs. 16-21) are comparable with *Isochilina* sp., but have more blunt mid-ventral alar processes.

Material.- Fourteen calcified valves; all the valves have their original shell material preserved, (Carter Collection, Redpath Museum).

Occurrence.- Beekmantown Group (S-9), Laurentides map-area, St. Lawrence Lowlands.

Order PALAEOCOPIDA Henningsmoen 1953

(*nom. transl. et correct.* Scott *in* Moore 1961)

Diagnosis.- See Henningsmoen (1953a, p. 188) and Scott *in* Moore (1961, pp. Q110-Q111).

Remarks.- Palaeocopids are a large, diverse and now extinct group of ostracodes. Palaeocopids characteristically have long straight dorsal margins, well developed lobes, sulci and dimorphic features. Although the palaeocopids range from the Lower Ordovician to the Middle Permian, they are most common in Ordovician strata (Vannier *et al.* 1989). Little is known about the paleoecology of the palaeocopids, but palaeocopid rich faunas are most common in areas of stable carbonate platform

sedimentation and palaeocopid distribution patterns are probably strongly influenced by lithofacies (Vannier *et al.* 1989).

Before undertaking any discussion of palaeocopid taxonomy, an understanding of the unique terminology used to describe these ostracodes is needed. Kesling (1951), Henningsmoen (1953a, 1965) and Jaanusson (1957) have all reviewed and revised this terminology and their approach is followed here.

Despite over a century of study, palaeocopids are still one of the most misunderstood groups of fossils (Scott *in* Moore 1961, p. Q110). Their taxonomy is complex, and only limited taxonomic stability has been achieved.

The two founders of palaeocopid research, E.O. Ulrich in North America and T.R. Jones in Europe, made the first attempts to comprehensively classify palaeocopid ostracodes (Ulrich 1894 and Jones *in* Chapman 1901). The taxa established by both Ulrich and Jones were largely based on the nature of lobation (L) and sulcation (S). Dimorphism was unrecognised. As a consequence, many taxa were based on dimorphs or instars, and to add to this confusion, features like spines were used to help in classification. T.R. Jones and E. O. Ulrich gathered their taxa into "sack" genera and family "groups"; the nature of these genera and families clarified with their use as the building blocks for later classification schemes. Ulrich and Bassler's (1923a, 1923b) and Bassler and Kellett's (1934) classification schemes represented considerable advances and consolidated the family group approach to palaeocopid taxonomy. In 1936, Swartz published a benchmark study on the Siluro-Devonian ostracode faunas of the Appalachians. He established a number of new families and was the first to recognise the importance of dimorphism in palaeocopids. Classification based simply on L-S sculpture was largely discredited during the period 1949 to 1957 by the work of three Scandinavian scientists, Hessland (1949), Henningsmoen (1953a) and Jaanusson (1957), who stressed the use of dimorphic features as classificatory criteria. The *Treatise* (Moore 1961) synthesised the opinions

of a number of specialists into a sound classificatory framework and was the first real attempt to bring order and stability to palaeocope taxonomy. In a return to the old orthodoxy, Schallreuter (1988) has re-emphasised L-S sculpture as a taxonomically useful feature for lower level (genus and family) classification. Vannier *et al.* (1989) have recently reviewed European Ordovician ostracode faunas; their study provides an up-to-date overview of European palaeocopids.

In summary, palaeocopid taxonomy has developed through a series of *ad hoc* additions and amendments to pre-existing taxonomic schemes, and the resulting taxonomy is complex. Although the existing knowledge of the palaeocopids is not well organised or ordered, it is important that this information is utilised and built upon, because it is the only source from which new ideas about the palaeocopids can develop.

There is still no consensus as to whether the Palaeocopida should be considered as an ordinal or subordinal grouping. Some European workers like Jones (1986, p. 19) and Vannier *et al.* (1989, pp. 170-171) consider the Palaeocopa to be a suborder of the Order Beyrichiocopa Pokorný 1953, while North American workers like Swain, Copeland and Berdan follow Scott *in* Moore (1961, pp. Q110-Q111), and assign the Palaeocopida ordinal status; this practice is followed here. See Scott *in* Moore (1961, pp. Q81-Q82) for further discussion of the palaeocopids.

Suborder BEYRICHICOPINA Scott 1961

Diagnosis.- See Scott *in* Moore (1961, pp. Q111-Q112).

Remarks.- The Beyrichicopina are a group of palaeocopids characterised by histial, locular, velar or cruminal dimorphism; see Scott *in* Moore (1961, pp. Q83-Q85) for further discussion of the Beyrichicopina.

Superfamily BEYRICHIACEA Matthew 1886

(*nom. transl.* Ulrich and Bassler 1923)

Diagnosis.- See Levinson *in* Moore (1961, p. Q112) Martinsson (1962, p. 128) and Siveter (1980, pp. 18-19).

Remarks.- The Beyrichiacea are a group of straight hinged Paleozoic ostracodes that exhibit brood pouch or cruminal dimorphism. See Martinsson (1962) and Siveter (1980) for further discussion of the Beyrichiacea.

Family BEYRICHIIDAE Matthew 1886

(*nom. transl. et correct.* Ulrich 1894)

Diagnosis.- See Levinson and Moore *in* Moore (1961, p. Q112) and Martinsson (1962, p 131).

Remarks.- Martinsson (1963) restricted the Beyrichiidae to those subfamilies which "lack radial tubulosity in the flange ridge-like velum". See Siveter (1980, p. 19) for further discussion of the Beyrichiidae.

Genus *Bolbiprimitia* Kay 1940

Type species.- *Halliella fissurella* Ulrich and Bassler 1923

Diagnosis.- See Levinson and Moore *in* Moore (1961, p. Q114).

Occurrence.- Known from the Upper Ordovician to Lower Devonian of North America, (Copeland 1973).

Bolbiprimitia? schmitti Copeland 1973

Pl. 3, fig. 1; text-fig. 3a.

Synonymy.- ?1962 *Ctenobolbina obliqua* Kraft, p. 46, pl. 11, figs. 7-13; text-fig. 10j-k.

1973 *Bolbiprimitia? schmitti* Copeland, p. 8, pl. 3, figs. 29-31; pl. 8, fig. 4.

Text-fig. 3

a. *Bolbiprimitia? schmitti* Copeland 1973
Ellis Bay Formation, Anticosti Island, (A-15).

b. *Eurychilina reticulata* Ulrich 1889
Deschambault Formation, St. Lawrence Lowlands, (S-4).

c. *Eurychilina subradiata* Ulrich 1890
Table Cove Formation, western Newfoundland, (T-10).

d. *Eurychilina subradiata* Ulrich 1890
Table Cove Formation, western Newfoundland, (T-11).

e. *Eurychilina subradiata* Ulrich 1890
Deschambault Formation, St. Lawrence Lowlands, (S-4).

f. *Eurychilina strasburgensis* Kraft 1962
Deschambault Formation, St. Lawrence Lowlands, (S-4).

g. *Coelochilina* sp.
Deschambault Formation, St. Lawrence Lowlands, (S-4).

h. *Platybolbina shaleri* Copeland 1973
Ellis Bay Formation, Anticosti Island, (A-16).

i. *Platybolbina shaleri* Copeland 1973
Ellis Bay Formation, Anticosti Island, (A-16).

j. *Platybolbina* sp.
Deschambault Formation, St. Lawrence Lowlands, (S-18).

k. *Oepikium* sp. cf. *O. tenerum* (Öpik 1935)
Deschambault Formation, St. Lawrence Lowlands, (S-7).

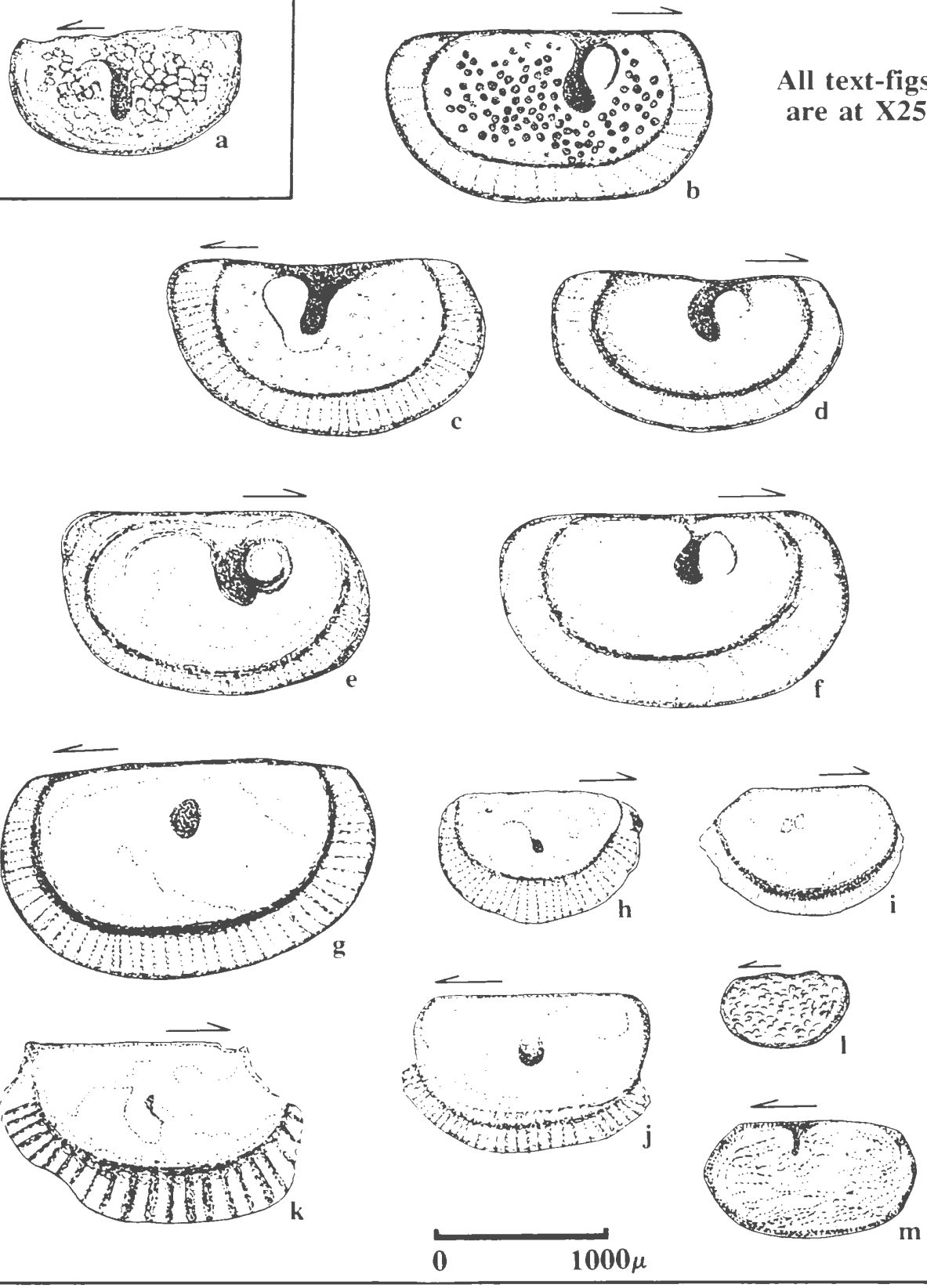
l. *Euprimitia labiosa* (Ulrich 1894)
Lourdes Formation, western Newfoundland, (L-9).

m. *Euprimitia?* sp.
Deschambault Formation, St. Lawrence Lowlands, (S-4).

Family BEYRICHIIDAE
Matthew 1886

Family EURYCHILINIDAE Ulrich and Bassler 1923

All text-figs.
are at X25



?1973 *Chilobolbina?* sp. Copeland, pp. 11-12, pl. 1, figs. 31-32.

Holotype.- *Bolbiprimitia? schmitti* Copeland 1973, p. 8, pl. 3, fig. 29.

Diagnosis.- See Copeland (1973, p. 8).

Description.- Domicilium subovate and dorsally truncate. Valves amplete; HV and HD at about mid-length, LV at or just below dorsal margin. Dorsal margin straight, ventral margin convex. Anterior margin broadly rounded, posterior margin more narrowly rounded. Anterior cardinal angle about 100°, posterior cardinal angle about 90°. Deep, distinctive, groove-shaped median sulcus (S2), posterior of low L2. Surface of domicilium coarsely reticulate. Narrow smooth velum extends around entire free margin. Subvelar field smooth and slightly concave; marginal ridge along contact margin.

Measurements.- LV 1175 μ, 1125 μ.
HV 700 μ, 650 μ.

Remarks.- Because the present collections are small and contain no heteromorphs, the dimorphic character of *Bolbiprimitia? schmitti* is unknown and assignment of this taxon to the genus *Bolbiprimitia* is tentative. The taxon identified as *Ctenobolbina obliqua* by Kraft (1962) has a similar sulcus to *Bolbiprimitia? schmitti* and is tentatively included in synonymy for future reference.

Material.- Two valves and three broken valves.

Occurrence.- Members 1 (A-7) and 4 (A-15), Ellis Bay Formation, Anticosti Island.

Superfamily EURYCHILINACEA Ulrich and Bassler 1923

(*nom. transl.* Jaanusson 1957)

Diagnosis.- See Jaanusson (1957, pp. 228-229), Schallreuter (1975a, p. 143) and Vannier *et al.* (1989, p. 171).

Remarks.- Eurychilinacean ostracodes generally exhibit marginal and velar dimorphism, in which the velum is typically tubulose (Vannier *et al.* 1989).

Family EURYCHILINIDAE Ulrich and Bassler 1923

(*nom. transl.* Henningsmoen 1953a)

Diagnosis.- See Henningsmoen (1953a, p. 263), Jaanusson (1957, pp. 229-230), Levinson and Moore *in* Moore (1961, p. Q142), Kraft (1962, p. 35), Schallreuter (1975a, p. 161) and Jones (1986, p. 19).

Remarks.- Eurychilinids characteristically have a single, well developed sulcus and a tubulose frill. The eurychilinids have been subdivided into a number of subfamilies based on the variability of velar dimorphism. This approach is not followed here, and the eurychilinids are simply divided into genera on the basis of variation in overall morphology.

Genus *Eurychilina* Ulrich 1889

Type species.- *Eurychilina reticulata* Ulrich 1889

Diagnosis.- See Ulrich and Bassler (1923a, p. 303) and Levinson and Moore *in* Moore (1961, p. Q142).

Remarks.- The various species of *Eurychilina* were established largely on the basis of ornamental variation. These differences in ornamentation can probably be accounted for by eco-phenotypic variation, together with differences in preservation (moulds, casts etc.) and preparation methods (acids, vibra-tool, washings etc.). Consequently many of the species of *Eurychilina* may be synonymous and in need of some creative lumping. Some species of *Eurychilina* are distinctly dimorphic, the heteromorphs having a sausage-shaped inflation formed along the ventral margin of the domicilium. Jaanusson (1957, pp. 230-233) discusses the nature of the eurychilinid frill in some detail. The genera *Chilobolbina* Ulrich and Bassler 1923a, *Laccochilina* Hessland 1949 and *Marquezina* Vannier 1986b are all similar to *Eurychilina*.

Occurrence.- Known from the Lower Ordovician to Lower Silurian of North America and Europe. (Levinson and Moore *in* Moore 1961, p. Q142).

***Eurychilina reticulata* Ulrich 1889**

Pl. 3, figs. 2-4; text-fig. 3b.

Synonymy.- **1889** *Eurychilina reticulata* Ulrich, pp. 52-53, pl. 9, figs. 9-9a.
1890a *Eurychilina reticulata* Ulrich; Jones, p. 539, pl. 20, figs. 13a-b.
1894 *Eurychilina reticulata* Ulrich; Ulrich, p. 660, pl. 44, fig. 1.
1894 *Eurychilina reticulata* var. *incurva* Ulrich, p. 660, pl. 43, fig. 2.
1908 *Eurychilina reticulata* Ulrich; Ulrich and Bassler, p. 298, text-fig. 46.
1923a *Eurychilina reticulata* Ulrich; Ulrich and Bassler, p. 303, fig. 16, no. 5.
1934 *Eurychilina reticulata* Ulrich; Bassler and Kellett, p. 20, fig. 7, no. 5.
1936 *Eurychilina reticulata* Ulrich; Swartz, pl. 78, fig. 3a.
?1937b *Bollia reticulata* Teichert, p. 110, pl. 22, fig. 13; pl. 23, fig. 1.
?1940 *Eurychilina reticulata* Ulrich; Kay, p. 250, (not figured).
?1940 *Eurychilina reticulata parvifrons* Kay, p. 250, pl. 31, figs. 3-4.
1944 *Eurychilina reticulata* Ulrich; Shimer and Shrock, p. 673, pl. 283, fig. 20.
1951 *Eurychilina reticulata* Ulrich; Kesling, pl. 2, fig. 3.
1956 *Eurychilina reticulata* Ulrich; Cornell, p. 37, pl. 10, figs. 2-9, (unpublished).
?1957 *Eurychilina reticulata* Ulrich; Carter, pp. 147-150, pl. 7, figs. 6a-d, (unpublished).
1957 *Eurychilina reticulata* var. *incurva* Ulrich; Carter, pp. 150-151, pl. 7, figs. 5a-c, 9, (unpublished).
1957 *Halliella bipunctata* Carter, pp. 173-175, pl. 9, figs. 3a-d, (unpublished).
1960 *Eurychilina reticulata* Ulrich; Kesling, pp. 355-356, pl. 2, figs. 1-3; pl. 3, figs. 1-6; pl. 4, figs. 1-2.
1961 *Eurychilina reticulata* Ulrich; Levinson and Moore *in* Moore, pp. Q142-Q143, figs. 77.3a-c.
1962 *Eurychilina reticulata* Ulrich; Swain, p. 731, pl. 109, fig. 10.
1987 *Eurychilina reticulata* Ulrich; Swain and Cornell, p. 108, pl. 8, figs. 3a-e; pl. 9, figs. 5a-b; pl. 13, figs. 2-6, 14-15.

Holotype.- *Eurychilina reticulata* Ulrich 1889, pp. 52-53, pl. 9, figs. 9-9a.

Diagnosis.- See Ulrich (1889, pp. 52-53), Kesling (1960, pp. 355-356) and Swain and Cornell (1987, p. 108).

Description.- Valves subovate to subelliptical in lateral view and dorsally truncate. Valves amplete; HV at about mid-length, LV at about mid-height. Dorsal margin long, straight; free margin broadly convex. Cardinal angles distinct; anterior cardinal angle about 120°, posterior cardinal angle about 110°. Domicilium evenly convex. Distinctive deep, reverse comma-shaped sulcus developed anterodorsally. Prominent rounded preadductorial node forms anterior margin of sulcus. Domiciliar surface coarsely reticulate. Slightly radiate velum extends around entire free margin. No dimorphism observed.

Measurements.- LV 1825 μ, 1800 μ, 1700 μ, 1675 μ, 1275 μ.
HV 1075 μ, 1075 μ, 1050 μ, 1000 μ, 800 μ.

Remarks.- Kesling (1960, p. 356) noted that *Eurychilina reticulata* exhibits velar dimorphism and went on to question whether this dimorphism reflects differences in the mode of life of the heteromorphs and tecnomorphs.

Material.- Eight very well-preserved valves, showing exquisite reticulation.

Occurrence.- Deschambault Formation (S-4), Laurentides map-area, St. Lawrence Lowlands.

Eurychilina subradiata Ulrich 1890

Pl. 4, figs. 1-5; text-figs. 3c-e.

Synonymy.- **1890** *Eurychilina subradiata* Ulrich, pp. 126-127, pl. 9, figs. 1a-c, 2a-c.
?1890 *Eurychilina longula* Ulrich, pp. 127-128, pl. 9, figs. 3-4.
1890 *Eurychilina granosa* Ulrich, p. 128, pl. 9, figs. 9-12.
1894 *Eurychilina subradiata* Ulrich; Ulrich, pp. 661-662, pl. 44, figs. 3, 4-4a.
1908 *Eurychilina subradiata* Ulrich; Ulrich and Bassler, p. 299, fig. 49.
1912 *Eurychilina subradiata* Ulrich; Ruedemann, pl. 9, fig. 16.

1926 *Eurychilina subradiata* Ulrich; Butts, p. 124, pl. 30, fig. 5.

1932 *Eurychilina subradiata* Ulrich; Bassler, pl. 10, fig. 14.

?1937a *Eurychilina punctata* Teichert, pp. 50-51, pl. 5, fig. 14.

1940 *Eurychilina subradiata* Ulrich; Kay, pp. 250-251, pl. 31, fig. 5.

1944 *Eurychilina subradiata* Ulrich; Shimer and Shrock, p. 675, pl. 283, figs. 17-19.

1956 *Eurychilina subradiata* Ulrich; Cornell, pp. 37-38, pl. 10, figs. 1a-b, (unpublished).

1957 *Eurychilina bunoda* Carter, pp. 141-143, pl. 7, figs. 4a-d, (unpublished).

1957 *Eurychilina minuta* Carter, pp. 145-147, pl. 7, figs. 7a-b, (unpublished).

1957 *Halliella bipunctata* Carter, pp. 173-175, pl. 9, figs. 3a-d, (unpublished).

1957 *Eurychilina cultrata* Harris, p. 231, pl. 7, figs. 11a-b.

?1957 *Eurychilina simplex* Harris, pp. 232-233, pl. 7, figs. 13a-b.

1957 *Eurychilina subradiata* Ulrich; Harris, pp. 233-234, pl. 7, figs. 12a-c, 14a-c.

1960 *Eurychilina subradiata* Ulrich; Kesling, pp. 356-357, pl. 4, fig. 3.

?1960 *Eurychilina* sp. Kesling, pl. 4, figs. 4-5.

?1961 *Eurychilina werneri* Levinson, p. 364, pl. 1, figs. 4a-b.

?1962 *Eurychilina bulbinoda* Kraft, pp. 38-39, pl. 10, figs. 4-8; text-figs. 13h-i.

?1962 *Eurychilina placida* Swain, p. 730, pl. 109, figs. 7a-f.

?1965 *Eurychilina ventrosa* Ulrich; Copeland, p. 12, pl. 3, figs. 16-17.

?1965 *Eurychilina* sp. cf. *Eurychilina reticulata* Ulrich; Copeland, pp. 11-12, pl. 3, figs. 18-19.

1965 *Eurychilina subradiata* Ulrich; Copeland, p. 13, pl. 4, figs. 6-13; pl. 10, figs. 15-17.

?1967 *Laccochilina (Eochilina) scrobiculata* Ivanova; Kanygin, pp. 25-26, pl. 4, fig. 1.

1971 *Eurychilina subradiata* Ulrich; Copeland *in* Steele and Sinclair, pl. 23, figs. 29-31.

1977a *Eurychilina subradiata* Ulrich; Copeland, pl. 1, fig. 19.

1977c *Eurychilina subradiata* Ulrich; Copeland, pl. 2, figs. 4, 9; pl. 3, fig. 6.

?1982 *Eurychilina? placida* Swain; Copeland, pl. 7, figs. 14-22; pl. 9, fig. 8.

1982 *Eurychilina subradiata* Ulrich; Warshauer and Berdan, p. H46, pl. 9, figs. 15-17.

1987 *Eurychilina subradiata* Ulrich; Swain and Cornell, p. 108, pl. 9, figs. 4a-b; pl. 13, fig. 13.

?1987 *Eurychilina micropunctata* Swain and Cornell, pp. 108-109, pl. 8, fig. 2; pl. 13, fig. 1.

?1987 *Eurychilina* sp. Berdan *in* Ross and James, p. 95, (not figured).

Holotype.- *Eurychilina subradiata* Ulrich 1890, pp. 126-127, pl. 9, figs. 1a-c, 2a-c.

Diagnosis.- See Ulrich (1890, pp. 126-127) and Kesling (1960, pp. 356-357).

Description.- *Eurychilina subradiata* is like *Eurychilina reticulata* (described earlier) except that: the lateral surface varies from smooth to finely punctate or papillate; the velum is wider, more outwardly flaring and has better developed radial striations; the subvelar field is concave and there is a narrow marginal ridge.

Measurements.- LV 2200 μ, 2100 μ, 2075 μ, 1675 μ, 1550 μ, 1500 μ.
HV 1100 μ, 1150 μ, 1175 μ, 900 μ, 925 μ, 850 μ.

Remarks.- The ontogenetic and dimorphic character of *Eurychilina subradiata* remains uncertain (Kesling 1960, p. 357). Whether species like *Eurychilina ventrosa* Ulrich 1894 and *Eurychilina indivisa* Levinson 1961, are heteromorphs of *Eurychilina subradiata*, or separate species is unknown. Jaanusson (1957, p. 232) illustrates a transverse section through *Eurychilina subradiata*, showing the nature of the eurychilinid frill and its outer wall. *Eurychilina reticulata* Ulrich 1889 is very similar to *Eurychilina subradiata*; both species were described by Ulrich from the "Trenton shales of Minnesota" and when illustrated side by side (Ulrich 1894, pl. 43, figs. 1, 3-4) appear almost identical. *Eurychilina reticulata* and *Eurychilina subradiata* are probably synonymous, but are kept separate here because continuous variation between these two morphotypes cannot be demonstrated in the current collections.

Species like *Eurychilina sunbloodensis* Copeland 1974 and *Eurychilina prairiensis* Copeland 1974 are also similar to *Eurychilina subradiata*.

Material.- A total of twenty valves were examined, fifteen from (T-10, T-11) and five from (S-4). Most of the valves in samples T-10 and T-11 occur on the bedding surfaces of shaly limestones. When these surfaces are split, the valves usually break around the frill so that specimens consist of either an internal mould of the domicilium with the rest of the valve intact, or the inner surface of the domicilium with an external mould of the frill. In general, the specimens are well preserved, but require some fine-needle preparation for photography.

Occurrence.- *Eurychilina subradiata* occurs in argillaceous ribbon limestones (T-10, T-11) at the top of the Table Cove Formation, western Newfoundland and in the irregularly-bedded, crystalline limestones of the Deschambault Formation (S-4), Laurentides map-area, St. Lawrence Lowlands.

Eurychilina strasburgensis Kraft 1962

Pl. 5, figs. 1-2; text-fig. 3f.

Synonymy.- ?1889 *Eurychilina manitobensis* Ulrich, pp. 53-54, pl. 9, figs. 10a-b.
?1956 *Eurychilina partifimbriata* Kay; Cornell, p. 37, pl. 9, figs. 10-15, (unpublished).
?1956 *Eurychilina ventrosa* Ulrich; Cornell, p. 38, pl. 9, figs. 16-17, (unpublished).
1962 *Eurychilina strasburgensis* Kraft, pp. 37-38, pl. 9, figs. 10-12; pl. 10, figs. 1-3; text-figs. 13q, 14a-b.
?1962 *Eurychilina strasburgensis* Kraft; Swain, pp. 730-731, pl. 109, fig. 9.
?1974 *Eurychilina prairiensis* Copeland, p. 18, pl. 4, figs. 3-4; pl. 7, figs. 4-15; text-fig. 6, no. 5.
?1987 *Eurychilina sugarcreekensis* Swain and Cornell, p. 109, pl. 8, figs. 4a-b.
?1987 *Eurychilina kayi* Swain and Cornell, p. 109, pl. 9, figs. 2a-c; pl. 12, fig. 13; pl. 13, figs. 7, 9.

Holotype.- *Eurychilina strasburgensis* Kraft 1962, pp. 37-38, pl. 9, figs. 10-12; pl. 10, figs. 1-3; text-figs. 13q, 14a-b.

Diagnosis.- See Kraft (1962, pp. 37-38).

Description.- *Eurychilina strasburgensis* is like *Eurychilina reticulata* (described earlier), except that: the valves are slightly postplete; the lateral surface is rounded, swollen and smooth to finely granulose; the velum is wider, more inflated and somewhat striate.

Measurements.- LV 2075 μ, 1950 μ, 1925 μ, 1875 μ, 1800 μ.
HV 1175 μ, 1225 μ, 1150 μ, 1100 μ, 1075 μ.

Remarks.- The swollen velum in *Eurychilina strasburgensis* may act as a brood pouch and *Eurychilina strasburgensis* could simply be the heteromorph of *Eurychilina subradiata* or *Eurychilina reticulata*.

Material.- Eight calcified valves; all the specimens still have their original shell material preserved.

Occurrence.- Deschambault Formation (S-4), Laurentides map-areas, St. Lawrence Lowlands.

Genus *Coelochilina* Ulrich and Bassler 1923

Type species.- *Eurychilina aequalis* Ulrich 1890

Diagnosis.- See Ulrich and Bassler (1923a, p. 303), Bassler and Kellett (1934, p. 20) and Levinson and Moore *in* Moore (1961, p. Q144).

Remarks.- Ulrich and Bassler (1923a, p. 303) established *Coelochilina* for eurychilinids that have a simple sulcus and lack a preadductoral node.

Occurrence.- Known from the Middle Ordovician to Lower Silurian of North America and Europe, (Levinson and Moore *in* Moore 1961, p. Q144).

Coelochilina sp.

Pl. 5, fig. 3; pl. 6, fig. 1; text-fig. 3g.

Synonymy.- ?1936 *Eurychilina kukersiana* (Bonnema); Öpik, pp. 84-85, pl. 1, fig. 9; pl. 11, figs. 1-6.

?1954a *Platybolbina* sp. cf. *Platybolbina plana* (Krause); Henningsmoen, p. 87, pl. 3, figs. 1-8.

1957 *Coelochilina dorsotropis* Carter, pp. 158-160, pl. 8, figs. 4a-d, (unpublished).

?1959 *Laccochilina (Laccochilina)? kuckersiana* (Bonnema); Sarv, pl. 1, figs. 8-13.

?1962 *Laccochilina (Laccochilina) phracta* Kesling, Hall and Melik, pp. 208-209, pl. 1, figs. 3-4.

?1962 *Apatochilina* sp. aff. *Apatochilina obesa* (Ulrich); Swain, p. 732, pl. 109, fig. 11.

?1967 *Laccochilina (Eochilina) tumefacta* Kanygin, pp. 28-29, pl. 4, fig. 10.

?1971 *Coelochilina laccochilinoides* Ivanova; Kanygin, pp. 37-39, pl. 2, figs. 1-6.

?1971 *Coelochilina exuviata* Kanygin, pp. 41-42, pl. 2, fig. 8.

?1975 *Platybolbina (Rimabolbina) rima* Schallreuter; Schallreuter, p. 150, pl. 2, figs. 1-6.

?1979 *Eochilina (Eochilina) invitabilis* Ivanova; Ivanova, p. 45, pl. 1, fig. 5.

?1980 *Actinochilina prochilinoides* Schallreuter, pp. 3-6, pl. 1, figs. 1-4; pl. 2, figs. 1-3.

Description.- Domicilium subquadrate and dorsally truncate. HD at about mid-length, LD at about mid-height. Dorsal margin straight and subparallel to adventral margin. Anterior and posterior margins evenly rounded. Anterior and posterior cardinal angles at about 110°. Broadly convex lateral surface with a large, central, deeply impressed suboval pit that is surrounded by a low rounded ridge. Lateral surface smooth to finely papillate. Narrow, radially striate and outwardly flaring velum extends around entire free margin. Junction between frill and domicilium sharp and angular. No dimorphism observed.

Measurements.- LV 1975 μ, 1900 μ, 1875 μ, 1250 μ.
HV 1250 μ, 1250 μ, 1225 μ, 800 μ.

Remarks.- *Coelochilina* sp. is assigned to *Coelochilina* because its characteristics correspond more closely to this genus, than to any other. A number of taxa assigned to the following genera *Eurychilina* Ulrich 1889, *Platybolbina* Henningsmoen 1953, *Coelochilina* Ulrich and Bassler 1923a, *Laccochilina* Hessland 1949, *Eochilina* Ivanova 1964 and *Actinochilina* Jaanusson 1957 are tentatively included in synonymy with *Coelochilina* sp. However, until larger collections of *Coelochilina* sp. are available and the type material of the tentative synonyms is examined in detail, synonymy cannot be assessed with certainty.

Material.- Material examined consists of two partially broken valves from the Carter Collection, Redpath Museum (S-10) and seven well-preserved valves from sample S-4.

Occurrence.- Deschambault Formation (S-4, S-10), Sorel and Laurentides map-areas, St. Lawrence Lowlands.

Genus *Platybolbina* Henningsmoen 1953

Type species.- *Primitia distans* Krause 1889

Diagnosis.- See Jaanusson (1957, pp. 259-263) and Levinson and Moore *in* Moore (1961, p. Q145).

Remarks.- *Platybolbina* was established for eurychilinids that have a distinctive subcentral muscle spot and in which S2 is faint or absent. The nomenclatural history of *Platybolbina* is rather complicated and is outlined by Jaanusson (1957, pp. 259-260). *Platybolbina* is similar to *Apatochilina* Ulrich and Bassler 1923; however in *Apatochilina* the frill extends around the entire free margin and the subcentral muscle scar is not well defined.

Occurrence.- Known from the Lower to Upper Ordovician of Europe and eastern North America, (Levinson and Moore *in* Moore 1961, p. Q145).

***Platybolbina shaleri* Copeland 1973**

Pl. 6, figs. 2-3; text-figs. 3h-i.

Synonymy.- ?1923b *Chilobolbina billingsi* Jones; Ulrich and Bassler, p. 518, pls. 7-9.

?1944 *Chilobolbina billingsi* Jones; Shimer and Shrock, p. 675, pl. 283, fig. 45.

?1953b *Platybolbina tiara densistriata* Henningsmoen, p. 53, pl. 5, figs. 14-15; pl. 8, fig. 21.

?1954a *Platybolbina* cf. *plana* Henningsmoen, p. 87, pl. 3, figs. 1-8.

?1957 *Platybolbina kapteyni* (Bonnema); Jaanusson, pp. 263-265, pl. 4, figs. 1-3; text-figs. 18c-d.

?1962 *Apatochilina punctata* Kraft, pp. 39-41, pl. 9, figs. 1-7; text-fig. 10i.

?1971 *Apatochilina?* sp. Copeland *in* Steele and Sinclair, pl. 23, fig. 15.

1973 *Platybolbina shaleri* Copeland, p. 11, pl. 1, fig. 30; pl. 3, figs. 32-34; pl. 6, figs. 16-18; pl. 7, figs. 11-15.

?1975a *Platybolbina (Reticulobolbina) kapteyni* (Bonnema); Schallreuter, p. 147, pl. 1, figs. 4-5.

1977a *Platybolbina shaleri* Copeland; Copeland, pl. 1, fig. 24.

?1977b *Platybolbina (Reticulobolbina) lenzi* Copeland, pp. 29-30, pl. 5, figs. 12-20.

?1978 *Platybolbina (Reticulobolbina) lenzi* Copeland; Copeland, p. 97, pl. 1, fig. 3.

1979 *Platybolbina (Platybolbina) kapteyni* (Bonnema); Ivanova, pl. 5, fig. 8; text-fig. 12.

1979 *Platybolbina (Platybolbina) temperata* Sarv; Ivanova, pl. 5, figs. 9-10.

?1985 *Platybolbina (Rimabolbina) omphalota* Kesling; Schallreuter and Siveter, pl. 68, fig. 1.

?1989 *Platybolbina (Reticulobolbina) lenzi* Copeland; Copeland, p. 13, pl. 1, figs. 1-3.

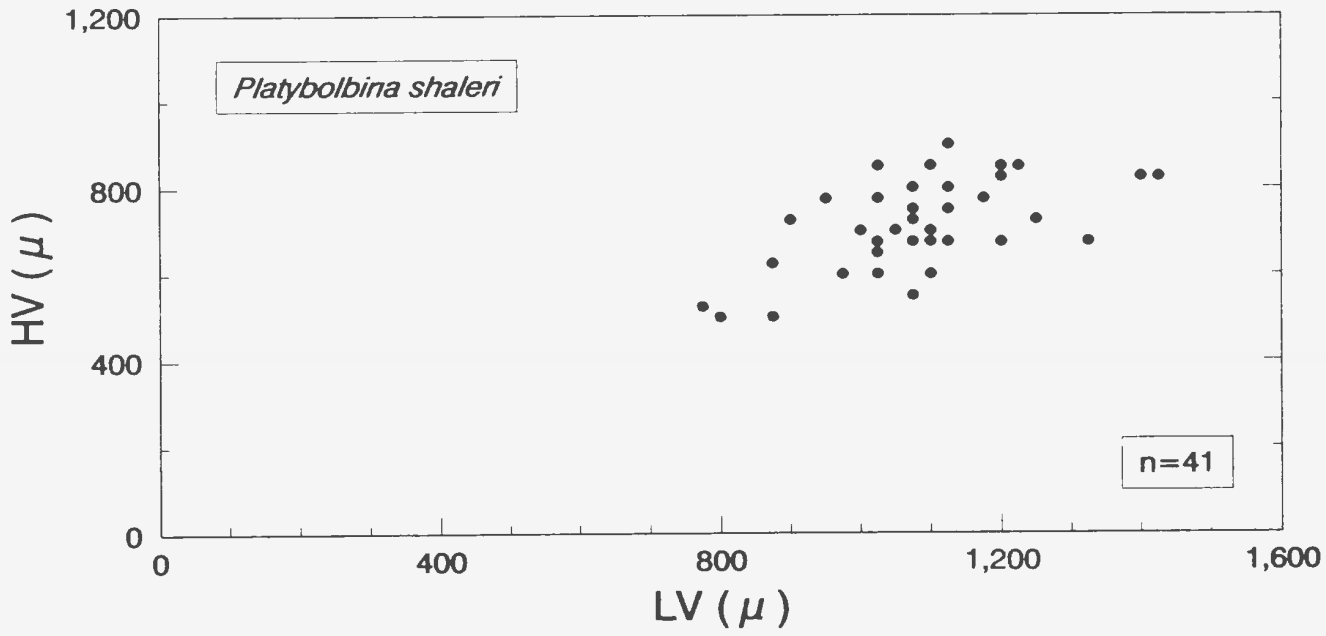
Holotype.- *Platybolbina shaleri* Copeland 1973, p. 11, pl. 6, fig. 18.

Diagnosis.- See Copeland (1973, p. 11).

Description.- Domicilium subovate and dorsally truncate. Valves including frill preplete; HV and HD anterior of mid-length, LD just above mid-height. Dorsal

margin long and straight; free margins broadly convex. Anterior cardinal angle about 120°, posterior cardinal angle about 90°. No sulcation, lobation or dorsal plica. Central pit surrounded by a smooth, ovate or tear-drop shaped muscle scar. Lateral surface finely reticulate. Broad radially striate velum, widest anteriorly, becoming narrower and ridge like posteriorly. Subvelar field smooth and slightly concave. Well developed marginal ridge around free margin. No dimorphism observed.

Measurements.- The specimens of *Platybolbina shaleri* that were measured exhibit a reasonable degree of size variation (Text-fig. 4), but no instar patterns can be recognised. More material is needed to ascertain whether the assemblage is size-sorted.



Text-fig. 4. Size dispersion diagram of *Platybolbina shaleri* Copeland 1973 from samples A-12 and A-16.

Remarks.- Until the nature of dimorphism in *Platybolbina shaleri* is firmly established, it is not possible to tell whether *Platybolbina shaleri* is synonymous with the similar taxa, *Bolbineossia (Bolbineossia) pineaulti* and *Bolbineossia*

(Brevibolbineossia) berdanae, that were described from the Silurian of Anticosti Island by Copeland (1974a, pp. 14-16). Apart from minor differences in the shape of the velar frill, *Platybolbina shaleri* is similar to *Tvaerenella tersa* Copeland 1965.

Material.- Forty-one valves, most of which are well preserved.

Occurrence.- Member 5 (A-12, A-16), Ellis Bay Formation, Anticosti Island.

***Platybolbina* sp.**

Pl. 6, fig. 4; text-fig. 3j.

Synonymy.- **1957** *Macronotella reticulata* Carter, pp. 113-114, pl. 5, figs. 6a-c, (unpublished).

1957 *Macronotella velata* Carter, pp. 116-117, pl. 5, figs. 5a-f, (unpublished).

Description.- Domicilium subovate and dorsally truncate. HV and HD at about mid-length, LV above mid-height. Hingeline long straight; free margins evenly rounded. Anterior and posterior cardinal angles about 100°. Lateral surface evenly convex, no lobation or sulcation. Distinctive, tear-drop shaped muscle scar just below mid-valve. Broad, radially striate velar frill around entire free margin. Domiciliar surface finely granulose.

Measurements.- LV 1875 μ, 1800 μ, 1550 μ.
HV 1325 μ, 1075 μ, 1050 μ.

Remarks.- *Platybolbina* sp. is similar to *Platybolbina (Rimabolbina) nitida* (Ulrich 1890) as described by Warshauer and Berdan (1982, pp. H47-H48), but without more material it is not possible to confirm whether these taxa are synonymous.

Material.- Five moderately well-preserved valves, some have broken velar frills, (Carter Collection, Redpath Museum).

Occurrence.- Deschambault Formation (S-18), Grondines map-area, St. Lawrence Lowlands.

Genus *Oepikium* Agnew 1942

(*nom. correct.* Jaanusson 1957)

(=*Biflabellum* Öpik 1935 *non* Döderlein 1913)

Type species.- *Biflabellum tenerum* Öpik 1935

Diagnosis.- See Kesling (1955, p. 266-268), Jaanusson (1957, pp. 407-408), Hessland *in* Moore (1961, p. Q149) and Schallreuter (1975a, p. 175).

Remarks.- When Öpik (1935) established *Biflabellum*, he used a name which had already been used (*Biflabellum* Döderlein 1913). Because of this homonymy Agnew (1942) replaced Öpik's generic name with a new name *Öpikium*, the spelling of which was subsequently corrected to *Oepikium* by Jaanusson (1957).

Occurrence.- Known from the Lower to Upper Ordovician of Europe and North America, (Hessland *in* Moore 1961, p. Q149).

Oepikium sp. cf. *Oepikium tenerum* (Öpik 1935)

Pl. 6, fig. 5; text-fig. 3k.

Synonymy.- **?1936** *Biflabellum tenerum* Öpik; Öpik 1936, p. 104, pl. 5, figs. 1-4; pl. 14, fig. 12.
?1951 *Öpikium tenerum* (Öpik); Kesling, pl. 8, figs. 1-2.
?1955 *Öpikium tenerum* (Öpik); Kesling, pp. 268-269, pl. 1, figs. 7a-10b.
1957 *Öpikium costivelum* Carter, pp. 224-226, pl. 12, figs. 1a-b, (unpublished).
?1959 *Oepikium tenerum* (Öpik); Sarv, pl. 27, figs. 1-5.
?1961 *Oepikium tenerum* (Öpik); Hessland *in* Moore, p. Q149, figs. 81.3a-b.
?1965 *Oepikium* sp. Copeland, p. 18, pl. 11, fig. 20.
?1975a *Oepikium tenerum* (Öpik); Schallreuter, pp. 178-179, pl. 11, figs. 3, 8.
?1977c *Oepikium* sp. Copeland, pl. 5, fig. 6.
?1979 *Oepikium tenerum* (Öpik); Ivanova, p. 17, text-figs. 14a-c.

Description.- Domicilium subelliptical and dorsally truncate. Valves including frill postplete. HD at mid-length, HV slightly posterior of mid-length, LV at about mid-height. Anterior cardinal angle about 110°, posterior cardinal angle about 100°. Hinge line straight, remaining domicilial margins evenly rounded. L1 and L2, low and indistinct. Shallow, subvertical, anteromedian sulcus (S2). Low rounded node forms anterior margin of sulcus. Broad, radially costate and outwardly flaring velar frill, extends from near anterior margin to mid-posterior margin. Frill, narrow and finely ribbed anteriorly, becoming wider and more coarsely ribbed posteriorly. Junction between frill and domicilium sharp. Domicilial surface smooth.

Measurements.- LV 1625 μ, 1275 μ.
HV 1100 μ, 925 μ.

Remarks.- Without more material, it is not possible to assess whether *Oepikium* sp. cf. *Oepikium tenerum* is synonymous with *Oepikium tenerum*. Dimorphism was not observed in *Oepikium* sp. cf. *Oepikium tenerum*, probably because of the limited number of specimens in the current collections.

Material.- Five well-preserved calcified valves, all the specimens are partly broken, (Carter Collectior, Redpath Museum).

Occurrence.- Deschambault Formation (S-7), Laval map-area, St. Lawrence Lowlands.

Genus *Euprimitia* Ulrich and Bassler 1923

Type species.- *Primitia sanctipauli* Ulrich 1894

Diagnosis.- See Ulrich and Bassler (1923a, p. 300) and Levinson and Moore *in* Moore (1961, pp. Q144-Q145).

Occurrence.- Known from the Lower Ordovician to Lower Silurian of North America and Europe, (Levinson and Moore *in* Moore 1961, pp. Q144-Q145).

Euprimitia labiosa (Ulrich 1894)

Pl. 6, figs. 6-7; text-fig. 3l.

Synonymy.-

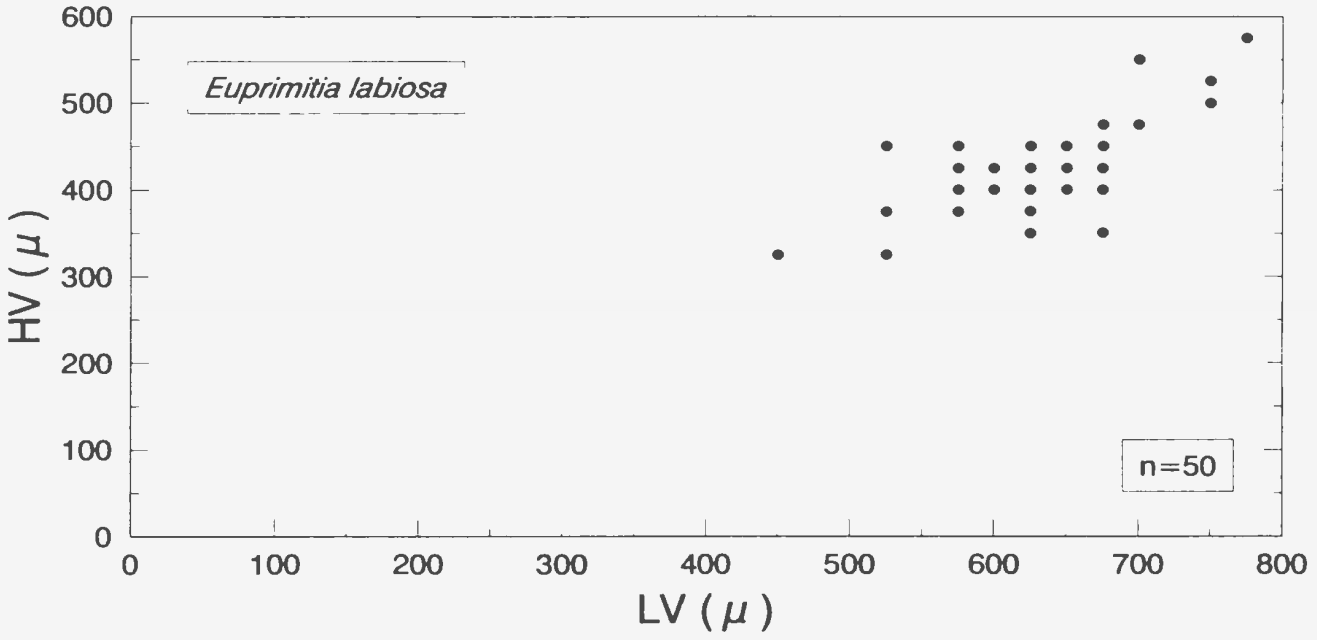
1894 *Halliella labiosa* Ulrich, p. 656, pl. 46, figs. 43-46.
1934 *Halliella labiosa* Ulrich; Kay, pp. 332-333, pl. 44, figs 17-18.
1934 *Halliella linepunctata* Kay, pp. 333-334, pl. 44, figs. 19-21.
1940 *Euprimitia labiosa* (Ulrich); Kay, p. 252, pl. 31, figs. 16-18.
1940 *Euprimitia linepunctata* (Kay); Kay, pp. 252-253, pl. 31, fig. 19.
1944 *Halliella labiosa* Ulrich; Shimer and Shrock, p. 665, pl. 281, figs. 15-17.
1948 *Halliella labiosa* Ulrich; Wright, pl. 3, figs. 36-38, (unpublished).
1952 *Euprimitia labiosa* (Ulrich); Moore, Lalicker and Fischer, p. 526, fig. 14.3, no. 7.
1956 *Euprimitia labiosa* (Ulrich); Cornell, pp. 26-27, pl. 8, figs. 16-20, (unpublished).
?1957 *Euprimitia elegans* Harris, pp. 198-199, pl. 6, figs. 13a-b.
1957 *Halliella labiosa* Ulrich; Harris, pp. 200-201 *pars*, pl. 6, figs. 16a-b, *non* figs. 14-15.
1961 *Euprimitia labiosa* (Ulrich); Levinson and Moore *in* Moore, pp. Q144-Q145, figs. 78.9a-e.
1962 *Euprimitia labiosa* (Ulrich); Kraft, p. 26, pl. 7, figs. 6-13; text-figs. 13a-c.
1965 *Euprimitia labiosa* (Ulrich); Copeland, p. 11, pl. 11, figs. 6, 8.
1965 *Euprimitia linepunctata* (Kay); Copeland, p. 11, pl. 11, fig. 12.
1972 *Euprimitia labiosa* (Ulrich); Bolton and Copeland, pl. A, fig. 2.
1977a *Euprimitia labiosa* (Ulrich); Copeland, pl. 1, fig. 8.
1977 *Euprimitia linepunctata* (Kay); Copeland *in* Copeland and Bolton, pl. 1.1, fig. 22.
?1982 *Euprimitia? krafti* Copeland; Copeland, pl. 1, figs. 27-29.
1987 *Euprimitia labiosa* (Ulrich); Swain and Cornell, pp. 109-110, pl. 5, fig. 7; pl. 6, figs. 1a-d; pl. 13, fig. 12.

Holotype.- *Halliella labiosa* Ulrich 1894, p. 656, pl. 46, figs. 43-46.

Diagnosis.- See Kay (1934, pp. 332-333 and 1940, p. 252).

Description.- Valves subelliptical and dorsally truncate. HV at or slightly posterior of mid-length, LV just above mid-height. Dorsal margin somewhat sinuous, free margins evenly rounded. Anterior cardinal angle about 130°, posterior cardinal angle about 120°. Equivalved, with sharply raised lateral surface that slightly overhangs depressed free marginal surface. Rounded marginal rim encloses entire lateral surface. Distinct, narrow mid-dorsal sulcus. Surface punctate, punctae may be concentrically aligned around sulcus. Contact margin rimmed. No dimorphism observed.

Measurements.- The measured specimens of *Euprimitia labiosa* exhibit little size variation (Text-fig. 5). No instars can be recognised and the assemblage appears to be size-sorted.



Text-fig. 5. Size dispersion diagram of *Euprimitia labiosa* (Ulrich 1894) from samples L-8, L-9 and L-10.

Remarks.- *Euprimitia labiosa* and *Euprimitia linepunctata* are included in synonymy, because the only differences between them are minor variations in surface ornament.

The type species, *Euprimitia sanctipauli* (Ulrich 1894) lacks the raised marginal rim of *Euprimitia labiosa*, but is otherwise similar. Keenan (1951, p. 568) described two new species, *Euprimitia minuta* and *Euprimitia floris* which are, unfortunately, too poorly illustrated to recognise.

Material.- Three carapaces and forty-seven valves. Specimens are somewhat corroded and a few are flattened; no original shell material is preserved.

Occurrence.- Beach Point Member (L-8, L-9, L-10), Lourdes Formation, western Newfoundland.

***Euprimitia?* sp.**

Pl. 6, figs. 8-9; text-fig. 3m.

Synonymy.- **1957** *Euprimitia lineata* Carter, pp. 166-168, pl. 8, figs. 5a-e, (unpublished).

Description.- Valves subelliptical and dorsally truncate. HV at about mid-length, LV at about mid-height. Hingeline straight, ventral margin slightly convex; anterior and posterior margins evenly rounded. Anterior cardinal angle about 120°, posterior cardinal angle about 100°. Narrow, subvertical, anterodorsal sulcus. Rounded preadductorial node forms anterior margin of sulcus. Shallow groove defines a convex border anterodorsally and posterodorsally. Surface ornamented with a series of anastomosing undulate ridges.

Measurements.- LV 1175 μ, 1150 μ, 1100 μ, 1075 μ, 1025 μ.
HV 675 μ, 675 μ, 650 μ, 625 μ, 600 μ.

Remarks.- *Euprimitia?* sp. is only tentatively assigned to *Euprimitia*, because its ornament and preadductorial node are untypical of this genus. *Euprimitia?* sp. is similar to several of the species of *Milleratia* Swartz 1936 described by Kraft (1962, pp. 23-25).

Material.- Nineteen calcified valves; material consists of fifteen valves from the Carter Collection, Redpath Museum (S-10, S-18) and four well-preserved valves from sample (S-4).

Occurrence.- Deschambault Formation (S-4, S-10, S-18), Laurentides, Sorel and Grondines map-areas, St. Lawrence Lowlands.

Superfamily HOLLINACEA Swartz 1936

(*nom. transl.* Jaanusson 1957)

Diagnosis.- See Jaanusson (1957, pp. 375-377) and Scott and Moore *in* Moore (1961, p. Q133).

Remarks.- The Hollinacea are a large diverse group of predominantly Lower Paleozoic palaeocopids. Hollinaceans vary from non-sulcate to quadrilobate and exhibit many types of dimorphic variation.

Family SIGMOOPSIDAE Henningsmoen 1953

(*nom. correct.* Jaanusson 1957)

Diagnosis.- See Jaanusson (1957, pp. 377-379) and Kesling *in* Moore (1961, p. Q155).

Genus *Sigmobolbina* Henningsmoen 1953

Type species.- *Entomis oblonga* var. *kuckersiana* Bonnema 1909

Diagnosis.- See Levinson *in* Moore (1961, p. Q160) and Jaanusson (1966, pp. 18-19).

Occurrence.- Known from the Middle Ordovician of Europe, (Levinson *in* Moore (1961, p. Q160).

Sigmobolbina? sp.

Pl. 7, fig. 1; text-fig. 7a.

Synonymy.- ?**1957** *Bellornatia mclishi* Harris, pp. 211-212, pl. 7, figs. 4a-b.

Description.- Carapace subelliptical and dorsally truncate. HV just anterior of mid-length, LV at about mid-height, WV posteroventrally. Dorsal margin straight, ventral margin convex. Anterior margin more broadly rounded than posterior margin. Anterior cardinal angle about 140°, posterior cardinal angle about 100°. Carapace flares out ventrally, becoming extremely thickened along the flattened ventral margin. Narrow median sulcus divides lateral margin into two lobes, a horseshoe shaped L1 and a larger posterodorsally directed L2. Raised, lobate lateral surfaces become keel-like ventrally, projecting beyond sunken contact margin. Surface finely granulose.

Measurements.- LV 725 μ.
HV 400 μ.

Remarks.- Lack of material, precludes recognition of the nature of dimorphism and ontogeny in *Sigmobolbina?* sp., so generic assignment is tentative. *Sigmobolbina?* sp. is similar to several species of *Ctenobolbina*, like *Ctenobolbina inflata* Harris 1957 and *Ctenobolbina projecta* Harris 1957. *Sigmobolbina?* sp. is also similar to some species of *Winchellatia* Kay 1940 and *Henningsmoenia* Thorslund 1948.

Material.- One carapace, an internal mould.

Occurrence.- Beach Point Member (L-8), Lourdes Formation, western Newfoundland.

Genus *Winchellatia* Kay 1940

Type species.- *Winchellatia longispina* Kay 1940

Diagnosis.- See Kay (1940, pp. 253-254), Kesling *in* Moore (1961, pp. Q160-Q161) and Williams (1990, pp. 9-12).

Remarks.- *Winchellatia* is similar to a number of other genera, like *Polyceratella* Öpik 1937, *Levisulculus* Jaanusson 1957, *Collibolbina* Schallreuter 1967 and *Aloculatia* Schallreuter 1976.

Occurrence.- Known from the Middle to Upper Ordovician of North America and Europe, (Kesling *in* Moore 1961, pp. Q160-Q161).

***Winchellatia* sp.**

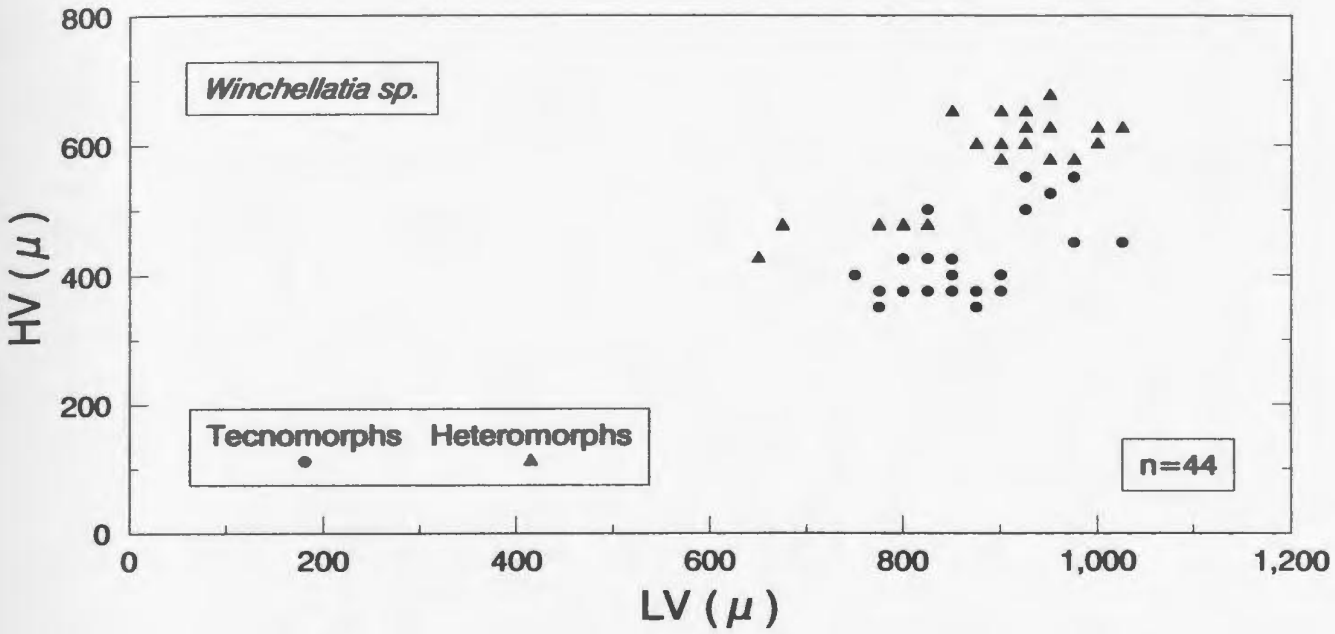
Pl. 7, figs. 2-3; text-figs. 7b-c.

Synonymy.- ?1940 *Winchellatia initialis* (Ulrich); Kay, p. 254, pl. 32, figs. 9-11.
?1940 *Winchellatia minnesotensis*; Kay, p. 255, pl. 32, figs. 13-19.
?1957 *Winchellatia cornuta* Harris, p. 220, pl. 9, figs. 4a-4b.
?1961 *Winchellatia lansingensis* Kay; Kesling *in* Moore, pp. Q160-Q161, figs. 89.8a-d.
1977 *Winchellatia* sp. aff. *Winchellatia minnesotensis* Kay; Copeland *in* Copeland and Bolton, pl. 1.1, figs. 18-20.

Description.- Valves subovate and dorsally truncate. Valves preplete with a distinctive anterior swing. HV anterior of mid-height, LV just above mid-height, WV along the anteroventral margin. Posterior margin narrowly rounded, anterior margin more broadly rounded. Anterior cardinal angle about 120°, posterior cardinal angle about 130°. Lateral surface relatively flat. Lobation poorly developed, L1 and L2 low, even. Sulcation restricted to an anterocentral, groove-like and slightly curved S2. Prominent posteroventral alate projection. Well developed histial frill extends from the mid-anterior margin to the posteroventral margin. Frill, broad and well developed in heteromorphs; less well developed in tecnomorphs. Subhistial field sunken. Surface smooth to finely granular.

Measurements.- The specimens of *Winchellatia* sp. only exhibit a limited degree of size variation (Text-fig. 6). Two size groupings can be recognised; the larger group is dominated by heteromorphs while the smaller group consists mainly of

tecnomorphs. Tecnomorphs have a higher LV to HV ratio than heteromorphs (i.e., they are relatively more elongate).



Text-fig. 6. Size dispersion diagram of *Winchellatia* sp. from samples L-8, L-9, L-10 and L-11.

Remarks.- *Winchellatia* sp. was first illustrated by Copeland *in* Copeland and Bolton (1977) as *Winchellatia* sp. aff. *Winchellatia minnesotensis*, but was not described at that time. *Winchellatia* sp. is unlike other species of *Winchellatia*, but is not assigned a new specific name, because it is not certain whether the present specimens are juveniles or adults.

Material.- Twenty-five carapaces and twenty-six valves; most of the material consists of corroded to uncorroded internal moulds.

Occurrence.- Beach Point Member (L-8, L-9, L-10, L-11), Lourdes Formation, western Newfoundland.

Family TETRADELLIDAE Swartz 1936

Diagnosis.- See Scott and Kesling *in* Moore (1961, p. Q161) and Jones (1986, pp. 40-41).

Remarks.- The tetradellids vary from quadrilobate to almost non-sulcate. S2 is usually long and more or less sigmoidal. Velar, histial and locular dimorphism can be developed. See Henningsmoen (1953a, pp. 212-213 and 1965, pp. 349-350) and Schallreuter (1982) for further discussion of the tetradellids.

Subfamily TETRADELLINAE Swartz 1936

(*nom. transl.* Kay 1940)

Diagnosis.- See Jones (1986, p. 41).

Remarks.- Tetradellinae characteristically exhibit velar (usually locular) dimorphism and have a non-dimorphic histium. See Schallreuter (1966) for further discussion of the phylogeny of the Tetradellinae.

Genus *Tetradella* Ulrich 1890

Type species.- *Beyrichia quadrilirata* Hall and Whitfield 1875

Diagnosis.- After Scott and Kesling *in* Moore (1961, p. Q161) and Guber (1971, pp. 14-16). Valves subquadrate to subovate with straight dorsal margin and convex ventral margin. Quadrilobate, lobes simple or divided, L1 and L4 merge ventrally to form continuous lobe subparallel to free margin. L2 and L3 join ventral connecting lobe. Heteromorphs display distinctive anterior and anteroventral locular dimorphism.

Remarks.- *Tetradella* is one of the most important Ordovician ostracode genera; species of *Tetradella* exhibit histial, locular and domiciliar dimorphism. Guber (1971) discusses the history, taxonomy and dimorphism of *Tetradella*. The genus *Cerninella* Přibyl 1966 is similar to *Tetradella*.

Text-fig. 7

a. *Sigmobolbina?* sp.
Lourdes Formation, western Newfoundland, (L-8).

b, c. *Winchellatia* sp.
Lourdes Formation, western Newfoundland, (L-8).

d, f. *Tetradella quadrilirata* (Hall and Whitfield 1875)
Ellis Bay Formation, Anticosti Island, (A-16).

e. *Tetradella quadrilirata* (Hall and Whitfield 1875)
Ellis Bay Formation, Anticosti Island, (A-7).

g. *Tetradella quadrilirata* (Hall and Whitfield 1875)
Lourdes Formation, western Newfoundland, (L-11).

i, k. *Tetradella? newfoundlandensis* Copeland 1977
Lourdes Formation, western Newfoundland, (L-10).

j. *Tetradella? newfoundlandensis* Copeland 1977
Lourdes Formation, western Newfoundland, (L-4).

l, m. *Foramenella phippsi* Copeland 1973
Ellis Bay Formation, Anticosti Island, (A-16).

n, o. *Anticostiella ellisensis* Copeland 1973
Ellis Bay Formation, Anticosti Island, (A-7).

h, p. *Tullinnella? subquadrans* (Ulrich 1890)
Tétreauville Formation, St. Lawrence Lowlands, (S-12, S-8).

q. *Ctenobolbina ciliata* (Emmons 1855)
Tétreauville Formation, St. Lawrence Lowlands, (S-2).

r. *Ctenobolbina* sp.
Nicolet Formation, St. Lawrence Lowlands, (S-13).

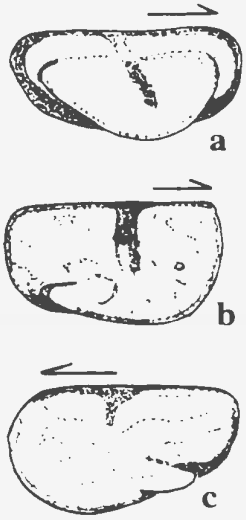
s. *Ceratopsis chambersi* (Miller 1874)
Neuville Formation, St. Lawrence Lowlands, (S-19).

t, u. *Ceratopsis chambersi* (Miller 1874)
Deschambault Formation, St. Lawrence Lowlands, (S-18, S-4).

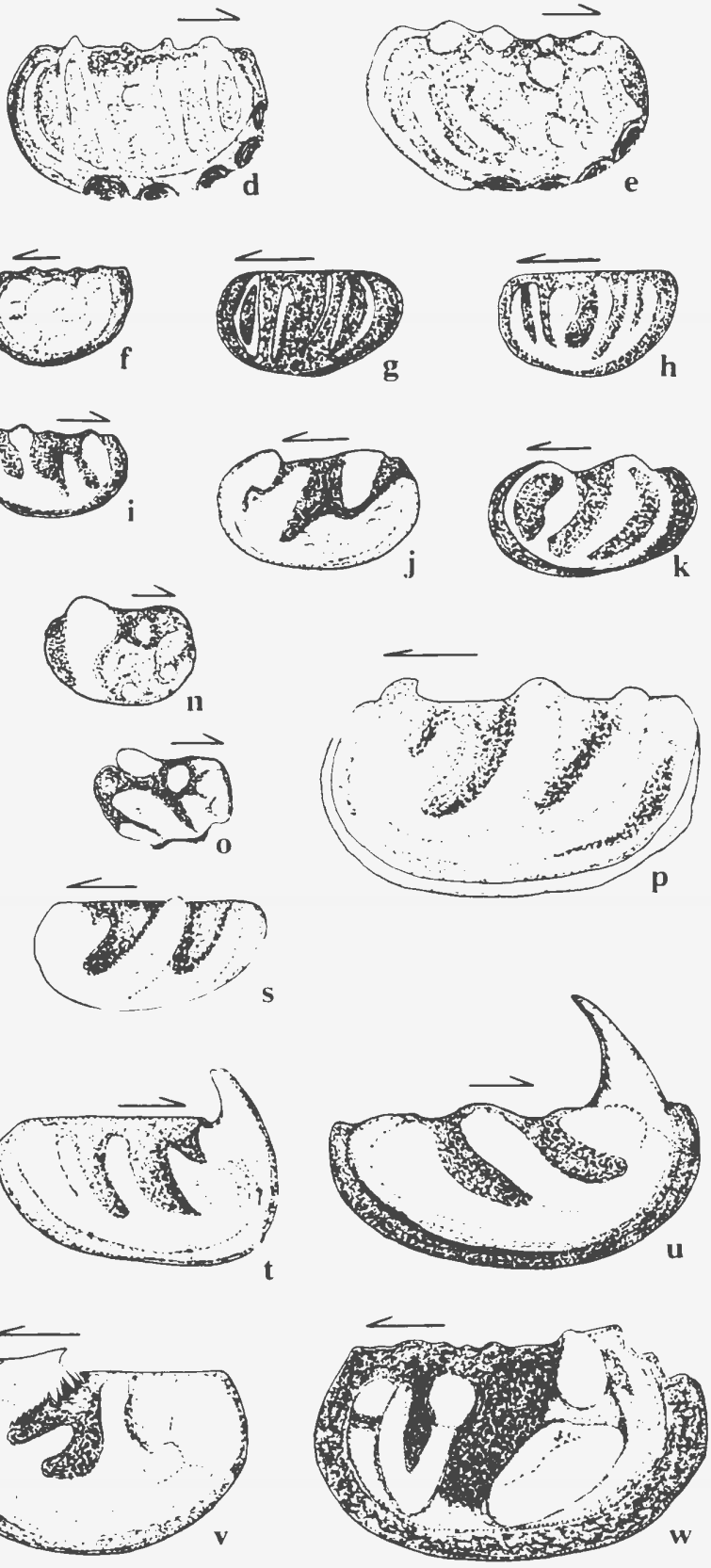
v. *Ceratopsis* sp.
Vauréal Formation, Anticosti Island, (A-2).

w. *Lambeodella?* sp.
Vauréal Formation, Anticosti Island, (A-6).

Family SIGMOOPSIDAE
Henningsmoen 1953



Family TETRADELLIDAE Swartz 1936



All text-figs.
are at X25

0 1000μ

Occurrence.- Known primarily from the Middle and Upper Ordovician of central and eastern North America, (Guber 1971, pp. 14-16).

***Tetradella quadrilirata* (Hall and Whitfield 1875)**

Pl. 7, figs. 4-10; text-figs. 7d-g.

Synonymy.- **1875** *Beyrichia quadrilirata* Hall and Whitfield, p. 105, pl. 4, figs. 6-7.

1889 *Strepula quadrilirata* (Hall and Whitfield); Ulrich, pp. 54-55, pl. 9, fig. 12.

1889 *Strepula quadrilirata* var. *simplex* Ulrich, p. 55, pl. 9, fig. 13.

1889 *Strepula lunatifera* Ulrich, p. 56, pl. 9, figs. 14-14b.

1894 *Tetradella quadrilirata* (Hall and Whitfield); Ulrich, pp. 679-680, pl. 46, figs. 1-5.

1894 *Tetradella lunatifera* (Ulrich); Ulrich, pp. 679-680, pl. 46, figs. 12-14.

1908 *Tetradella quadrilirata* (Hall and Whitfield); Ulrich and Bassler, pl. 39, figs. 4-5.

1908 *Tetradella lunatifera* (Ulrich); Ulrich and Bassler, pl. 39, fig. 6.

1923a *Tetradella (Beyrichia) quadrilirata* (Hall and Whitfield); Ulrich and Bassler, p. 311, text-fig. 20, no. 3.

?1928 *Tetradella simplex* (Ulrich); Bassler *in* Twenhofel, p. 342, (not figured).

?1928 *Tetradella lunatifera* (Ulrich); Bassler *in* Twenhofel, p. 342, (not figured).

1934 *Tetradella (Beyrichia). quadrilirata* (Hall and Whitfield); Bassler and Kellett, p. 338, fig. 11, no. 3.

?1934 *Tetradella ellipsilira* Kay, p. 339, pl. 45, figs. 10-15.

1934 *Tetradella ulrichi* Kay, pp. 339-340, pl. 45, figs. 16-19.

1936 *Tetradella ulrichi* Kay; Swartz, pl. 85, fig. 3a.

?1940 *Tetradella ellipsilira* Kay, p. 265, pl. 34, figs. 18-22.

1940 *Tetradella ulrichi* Kay, p. 265, pl. 34, fig. 23.

1944 *Tetradella quadrilirata* (Hall and Whitfield); Shimer and Shrock, p. 667, pl. 281, figs. 44-45.

1944 *Tetradella lunatifera* (Ulrich); Shimer and Shrock, p. 667, pl. 281, figs. 39-43.

1948 *Tetradella ellipsilira* Kay; Wright, pl. 5, fig. 26, (unpublished).

1948 *Tetradella quadrilirata* (Hall and Whitfield); Wright, pl. 5, figs. 27-28, (unpublished).

1948 *Tetradella ulrichi* Kay; Wright, pl. 5, figs. 29-32, (unpublished).

1951 *Tetradella quadrilirata* (Hall and Whitfield); Kesling, p. 160, pl. 7, figs. 5a-c.

1951 *Tetradella lunatifera* (Ulrich); Kesling, p. 160, pl. 7, figs. 6a-c.

1952 *Tetradella ellipsilira* Kay; Moore, Lalicker and Fischer, p. 525, fig. 14.2, nos. 10a-b.

1953 *Tetradella* sp. cf. *Tetradella quadrilirata* (Hall and Whitfield); Kesling and Hussey, pp. 89-91, pl. 2, figs. 1-24.

1956 *Tetradella ellipsilira* Kay; Cornell, pp. 46-47, pl. 12, figs. 1-9, 15, (unpublished).

1956 *Tetradella ulrichi* Kay; Cornell, p. 47, pl. 12, figs. 10-11, (unpublished).

1957 *Tetradella ulrichi* Kay; Carter, pp. 199-201, pl. 10, figs. 3a-d, (unpublished).

1961 *Tetradella quadrilirata* (Hall and Whitfield); Scott and Kesling *in* Moore, p. Q161, figs. 91.1a-c.

1961 *Tetradella lunatifera* (Ulrich); Scott and Kesling *in* Moore, p. Q161, figs. 91.2a-c.

?1961 *Tetradella ellipsellina* Kay; Scott and Kesling *in* Moore, p. Q161, figs. 91.4a-c.

1961 *Tetradella* sp. cf. *Tetradella quadrilirata* (Hall and Whitfield); Scott and Kesling *in* Moore, p. Q161, figs. 92.1a-h.

1962 *Tetradella quadrilirata* (Hall and Whitfield); Guber, pp. 73-82, pl. 2, figs. 1-12, (unpublished).

1962 *Tetradella lunatifera* (Ulrich); Guber, pp. 82-87, pl. 1, figs. 12a-b, 13a-b, (unpublished).

1965 *Tetradella kayi* Copeland, p. 22, pl. 1, figs. 5, 7-8.

1965 *Tetradella* sp. cf. *Tetradella ellipsilira* Kay; Copeland, p. 22, pl. 1, figs. 6, 9, 12.

1965 *Tetradella ulrichi* Kay; Copeland, p. 23, pl. 1, figs. 10-11.

1970 *Tetradella* sp. cf. *Tetradella lunatifera* (Ulrich); Copeland, p. 28, pl. 5, fig. 29.

?1971 *Tetradella ulrichi* Kay; Copeland *in* Steele and Sinclair, p. 42, pl. 23, figs. 19-20.

1971 *Tetradella quadrilirata* (Hall and Whitfield); Guber, pp. 17-18, pl. 2, figs. 5-12.

1971 *Tetradella scotti* Guber, pp. 18-19, pl. 1, figs. 1-16; pl. 2, figs. 1-4; text-fig. 8.

1971 *Tetradella lunatifera* (Ulrich); Guber, p. 19, pl. 3, fig. 11.

1971 *Tetradella buckensis* Guber, pp. 19-20, pl. 3, fig. 7.

?1971 *Tetradella egorowi* Guber, p. 21, pl. 3, figs. 5-6.

1972 *Tetradella ulrichi* Kay; Bolton and Copeland, pl. A, fig. 1.

1973 *Tetradella thomasi* Copeland, pp. 12-13, pl. 3, figs. 35-37; pl. 6, fig. 14; pl. 7, figs. 16-17; pl. 8, fig. 5.

1973 *Tetradella anticostiensis* Copeland, pp. 13-14, pl. 8, figs. 6-15; text-fig. 9.1a-c.

?1974 *Tetradella perplexa* Copeland, p. 21, pl. 2, figs. 1-7; text-fig. 6, nos. 1-2.

1977c *Tetradella buckensis* Kay; Copeland, pl. 1, figs. 8, 10, 13-14; pl. 4, fig. 16; pl. 5, fig. 11.

1977c *Tetradella ulrichi* Kay; Copeland, pl. 1, fig. 9; pl. 4, fig. 17; pl. 5, fig. 12.

1977c *Tetradella ellipsilira* Kay; Copeland, pl. 1, fig. 11.

1977a *Tetradella ulrichi* Kay; Copeland, pl. 1, fig. 3.

1977a *Tetradella buckensis* Guber; Copeland, pl. 1, figs. 14, 17.

1977a *Tetradella anticostiensis* Copeland; Copeland, pl. 1, fig. 23.

1977a *Tetradella thomasi* Copeland; Copeland, pl. 1, fig. 27.

1979a *Tetradella quadrilirata* (Hall and Whitfield); Ivanova, text-fig. 15.

1981 *Tetradella anticostiensis* Copeland; Copeland *in* Lespérance, p. 188, text-figs. 3.1a-c.

?1985 *Tetradella separata* Sidaraviciene; Schallreuter and Siveter, pl. 70, fig. 6.

1987 *Tetradella ellipsilira* Kay; Swain and Cornell, p. 110, pl. 4, figs. 4a-i; pl. 5, figs. 1a-b; pl. 12, fig. 4.

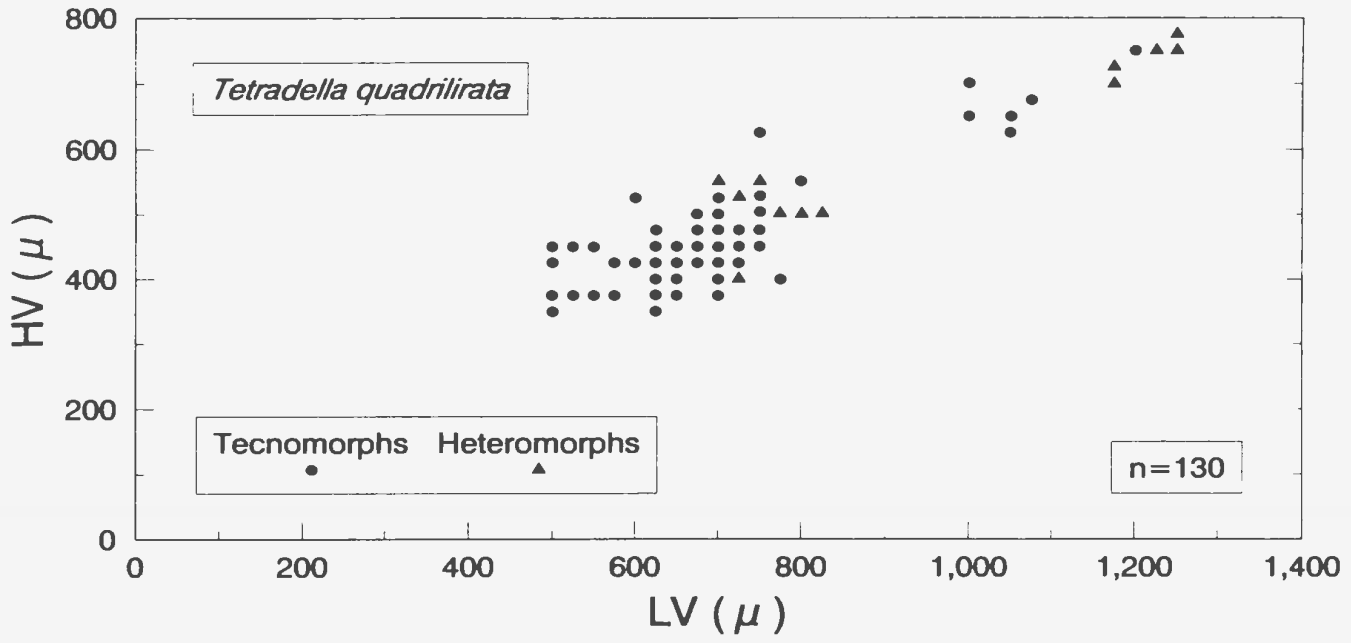
1987 *Tetradella ulrichi* Kay; Swain and Cornell, p. 111, pl. 5, figs. 2a-e.

Holotype.- *Beyrichia quadrilirata* Hall and Whitfield 1875, p. 105, pl. 4, figs. 6-7.

Diagnosis.- Modified from Hall and Whitfield (1875, p. 105) and Guber (1962, pp. 73-87 and 1971, pp. 17-19). *Tetradella* in which all four lobes are capped by one or more prominent crests, that are joined ventrally by a histial connecting crest. Projection of L1 and L3 above hinge line can make dorsal margin sinuous. S1 and S2 deeper than the triangular intracrestal area of L3, which is known as S3. Distinctive locular dimorphism developed in heteromorphs. Juveniles differ from adults by having a higher form (i.e., a lower LV to HV ratio) and less well developed lobation.

Description.- Valves subelliptical and dorsally truncate. HV at mid-length, LV at mid-height. Dorsal margin long and almost straight; free margins evenly convex. Cardinal angles about 130°. Quadrilobate, ventrally joined lobes capped by one or more crests. Bicrested L1 projects above dorsal margin. Prominent L2, expands dorsally into a preadductoral node. Lunate, bicrested L3 projects above dorsal margin, straight anterior crest and curved posterior crest join dorsally. L4, a fine crest parallel to posterior margin. S1 and S2 deeper than S3. Subhistial field channelled. Anteroventrally, heteromorphs have four subhistial crested loculi. Morphologically, juveniles differ from adults and at least five instars are known (Guber 1962, pp. 79-81). Loculi first develop in the adult minus three instar, while the LV to HV ratio gradually increases with each moult (Guber 1962). Crests and lobation progressively develop during ecdysis and are only fully developed in adults. Juveniles are much more common than adults.

Measurements.- The specimens of *Tetradella quadrilirata* fall into three size groups (Text-fig. 8): adult heteromorphs, adult tecnomorphs and a group of mainly tecnomorphic instars. Instars are much more common than adults; instar patterns are not well developed.



Text-fig. 8. Size dispersion diagram of *Tetradella quadrilirata* (Hall and Whitfield 1875) from samples A-7, A-15 and A-16.

Remarks.- Collections of *Tetradella* have often been oversplit for two reasons. First, differences between heteromorphs, tecnomorphs and juveniles of the same species were often unrecognised and second, taxa were split on the basis of intraspecific sculptural variation. Confusion over species, herein termed *Tetradella quadrilirata* (Hall and Whitfield 1875) arose when Hall and Whitfield (1875) described an instar, which became the species holotype. In 1889, Ulrich figured two immature specimens *Strepula quadrilirata* and *Strepula quadrilirata* var. *simplex*, together with an adult *Strepula lunatifera*, that became a taxon to which many subsequent specimens of *Tetradella quadrilirata* were assigned. During the Twentieth Century splitting continued, with many similar specimens being described as numerous disparate taxa (see synonymy list and Guber 1971, pls. 1-3).

Material.- Material consists of ten poorly preserved valves and carapaces from samples (L-8, L-10, L-11), ten adult and one hundred and thirty-five juvenile valves

(all of which are well preserved) from samples (A-7, A-15, A-16) and twenty well-preserved calcified valves from the Carter Collection, Redpath Museum (S 20).

Occurrence.- Beach Point Member (L-8, L-10, L-11), Lourdes Formation, western Newfoundland; Members 1 (A-7), 4 (A-15) and 5 (A-16), Ellis Bay Formation, Anticosti Island; Upper Deschambault Formation (S-10), Sorel map-area, St. Lawrence Lowlands.

***Tetradella? newfoundlandensis* Copeland 1977**

Pl. 8, figs. 1-5; text-figs. 7i-k.

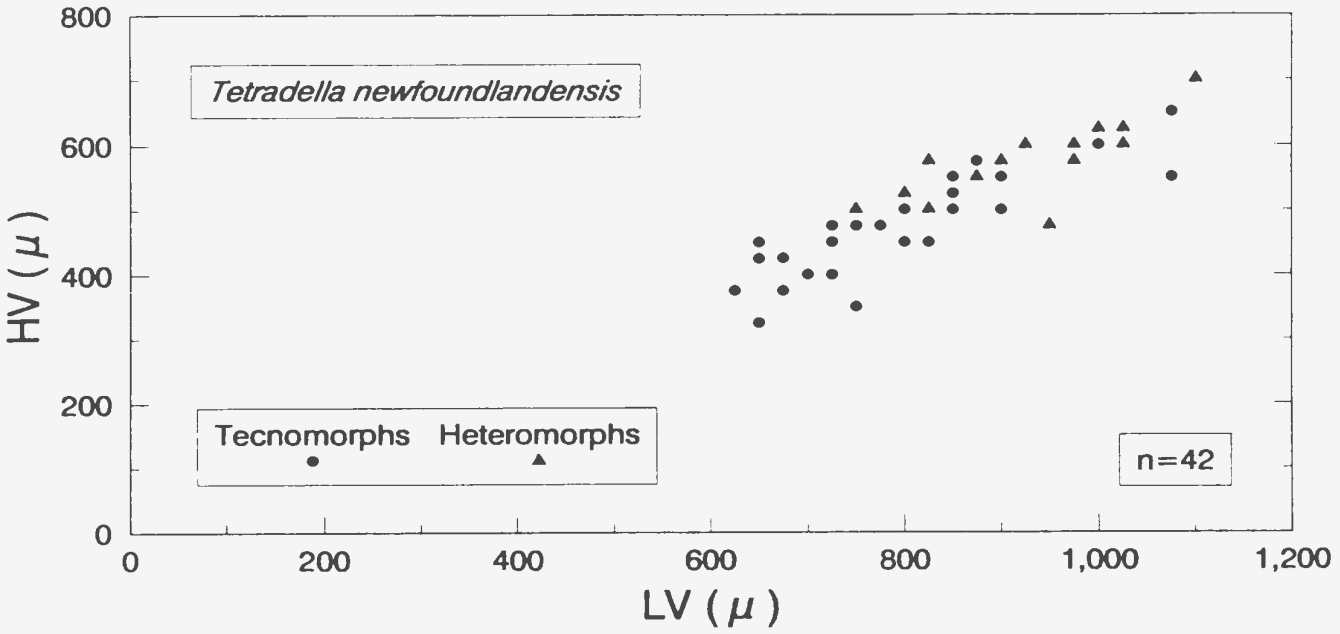
Synonymy.- **1977** *Tetradella? newfoundlandensis* Copeland *in* Copeland and Bolton, p. 3, pl. 1.1, figs. 9-13.

Holotype.- *Tetradella? newfoundlandensis* Copeland *in* Copeland and Bolton 1977, p. 3, pl. 1.1, figs. 12-13.

Diagnosis.- See Copeland *in* Copeland and Bolton (1977, p. 3).

Description.- Valves subelliptical and dorsally truncate. HV at mid-length, LV at mid-height. Dorsal margin long, straight; free margins evenly rounded. Cardinal angles about 120°. Quadrilobate, but only L1 and L3 are well developed. Lobes joined ventrally by a thickened connecting lobe, which extends from the base of L1 to the posterodorsal area. L1 and L3 subparallel, projecting above dorsal margin. L1 and L3 stub-like and undivided. L2 short. Posterodorsal extension of connecting lobe termed L4. Trisulcate, but S1 and S3 poorly developed. S2 distinctive, a broad depressed area between L1 and L3. Histial ridge marks distal edge of connecting lobe. Subhistial field upwardly inclined to contact margin. Dimorphic, heteromorphs have three anteroventral, subhistial loculi. Lobation is poorly developed in juveniles.

Measurements.- The specimens of *Tetradella? newfoundlandensis* exhibit continuous size variation and instar patterns cannot be recognised (Text-fig. 9). Heteromorphs generally have a lower LV to HV ratio than tecnomorphs.



Text-fig. 9. Size dispersion diagram of *Tetradella? newfoundlandensis* Copeland 1977 from samples L-2, L-4, L-8 and L-10.

Remarks.- Copeland *in* Copeland and Bolton (1977, p. 3) noted that *Tetradella? newfoundlandensis* was untypical of other species of *Tetradella* and questioned whether this species might be a dilobellid.

Material.- Five carapaces and thirty-seven valves; material consists of slightly corroded internal moulds, some of which are juveniles.

Occurrence.- Black Duck (L-2, L-4) and Beach Point (L-8, L-10) members, Lourdes Formation, western Newfoundland.

Genus *Foramenella* Stumbur 1956

Type species.- *Euprimitia parkis* Neckaja 1952

Diagnosis.- After Scott and Kesling *in* Moore (1961, p. Q162). Small, ova to elongate tetradellids, with conspicuous S2. Heteromorphs have five rimmed loculi.

Remarks.- Jaanusson (1957, p. 376) noted the similarities between *Foramenella* and the Devonian genera *Tetrasacculus* Stewart 1936 and *Bisacculus* Stewart and Hendrix 1945, but was not certain whether these genera were related.

Occurrence.- Known from Estonia and Anticosti Island, (Scott and Kesling *in* Moore 1961, p. Q162 and Copeland 1973, pp. 14-15).

Foramenella phippsi Copeland 1973

Pl. 8, figs. 6-9; pl. 9, figs. 1-3; text-figs. 7l-m.

Synonymy.- **1973** *Foramenella phippsi* Copeland, pp. 14-15, pl. 1, figs. 14-15; pl. 2, figs. 20-36; pl. 4, figs. 10-13; pl. 6, figs. 6, 19; pl. 7, figs. 2-3; text-fig. 9.3.

1977a *Foramenella phippsi* Copeland; Copeland, p. 17, pl. 1, figs. 22-26.

1981 *Foramenella phippsi* Copeland; Copeland *in* Lespérance, p. 188, text-figs. 3.2a-f.

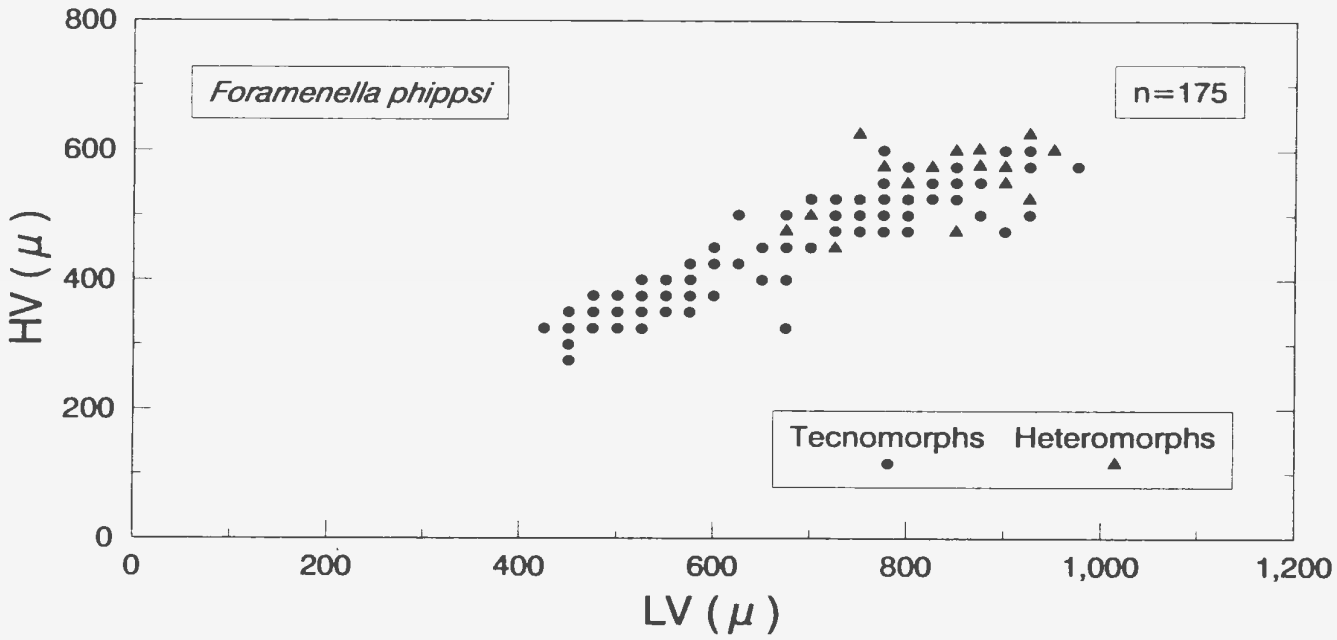
Holotype.- Copeland 1973, pp. 14-15, pl. 2, fig. 29.

Diagnosis.- After Copeland (1973, pp. 14-15). *Foramenella* with prominent loculi visible in lateral and ventral views of the heteromorphs. Juveniles, tecnomorphs and heteromorphs are morphologically distinct.

Description.- Valves subelliptical and slightly preplete. HV at about mid-length, LV just dorsal of mid-height. Dorsal margin straight, free margins evenly rounded. Hinge sunken; cardinal angles distinct, about 110°. Quadrilobate, lobes joined ventrally. L1 and L3-L4 project above hinge line. JUVENILES.- L1, L4 long thin;

L2 short with swollen node; L3 broad. S1 and S3 short slit-like; S2 deep reverse comma-shaped. Prominent marginal ridge. TECNOMORPHS.- L1-L2 low, broad and almost merged; L3 developed into a dorsal crest which partially encloses S2; L4 only partially separable from L3. S1 and S3 undeveloped; S2 a deep reverse comma-shaped pit. HETEROMORPHS.- Both L1-L2 and L3-L4 merged; S1 and S3 undeveloped; S2 deep, reverse comma-shaped. Five large conspicuous crested loculi along the anteroventral and ventral margins.

Measurements.- The specimens of *Foramenella phippsi* exhibit continuous size variation and no instar patterns can be recognised (Text-fig. 10). The smaller specimens are all tecnomorphs; heteromorphs generally have a lower LV to HV ratio than tecnomorphs.



Text-fig. 10. Size dispersion diagram of *Foramenella phippsi* Copeland 1973 from samples A-13, A-15 and A-16.

Remarks.- *Foramenella phippsi* is similar to several species of *Ctenobolbina* and *Dilobella* that were described from the Decorah Formation of Minnesota and Iowa by Ulrich (1894, pp. 674-675), Kay (1940, pp. 256-257) and Swain and Cornell (1987, p. 110). However in the genera *Ctenobolbina* and *Dilobella*, L1-L2 and L3 are ventrally connected into a U-shaped lobe, which conceals the anteroventral loculi in heteromorphs.

Material.- Sixty-eight carapaces, two hundred and thirty-five tecnomorphic and thirty-five heteromorphic valves; all the specimens are well preserved.

Occurrence.- Members 1 (A-7), 2 (A-10, A-13), 3 (A-11), 4 (A-14, A-15) and 5 (A 12, A-16), Ellis Bay Formation, Anticosti Island.

Genus *Anticostiella* Copeland 1973

Type species.- *Anticostiella ellisensis* Copeland 1973

Diagnosis.- See Copeland (1973, p. 9).

Occurrence.- Known from the Middle Ordovician to Lower Silurian of North America.

Anticostiella ellisensis Copeland 1973

Pl. 9, figs. 4-8; text-figs. 7n-o.

Synonymy.- ?1934 *Thomasatia falcicostata* Kay, pp. 337-338, pl. 46, figs. 13-23.
?1940 *Bromidella depressa* Kay, p. 263, pl. 34, figs. 12-15.
?1940 *Bromidella rhomboides* Kay, p. 263, pl. 34, fig. 1.
?1940 *Opikatia rotunda* Kay, p. 264, pl. 34, figs. 1-6.
?1940 *Opikatia emaciata* Kay, p. 264, pl. 34, figs. 7-11.
?1956 *Bromidella depressa* Kay; Cornell, p. 40, pl. 10, figs. 10-15; pl. 11, figs. 1-2, (unpublished).
?1957 *Eohollina depressa* (Kay); Harris, pp. 208-209, pl. 7, figs. 1a-b, 2a-d.
?1957 *Eohollina depressa* subsp. *papillata* Harris, pp. 209-210, pl. 7, figs. 3a-b.

?1962 *Tetradella* sp. Sarv, p. 118, pl. 5, fig. 19.

?1962 *Bromidella depressa* Kay; Kraft, p. 43, pl. 15, figs. 8-17; text-figs. 14g-h.

?1965 *Eohollina depressa* (Kay); Copeland, p. 9, pl. 8, figs. 14-16, 21-23.

1973 *Anticostiella ellisensis* Copeland, p. 9, pl. 3, figs. 12-17, 24; pl. 6, fig. 5; pl. 7, figs. 4-7.

?1974a *Anticostiella pustulosa* Copeland, pp. 40-41, pl. 9, figs. 1-14.

1977a *Anticostiella ellisensis* Copeland; Copeland, pl. 1, fig. 25.

?1982 *Eohollina depressa* (Kay); Copeland, p. 10, pl. 2, figs. 18-19; pl. 6, figs. 9-10; pl. 7, fig. 5.

?1987 *Bromidella depressa* Kay; Swain and Cornell, pp. 106-107, pl. 9, fig. 6; pl. 10, figs. 1a-g; pl. 11, figs. 3-4, 9-10.

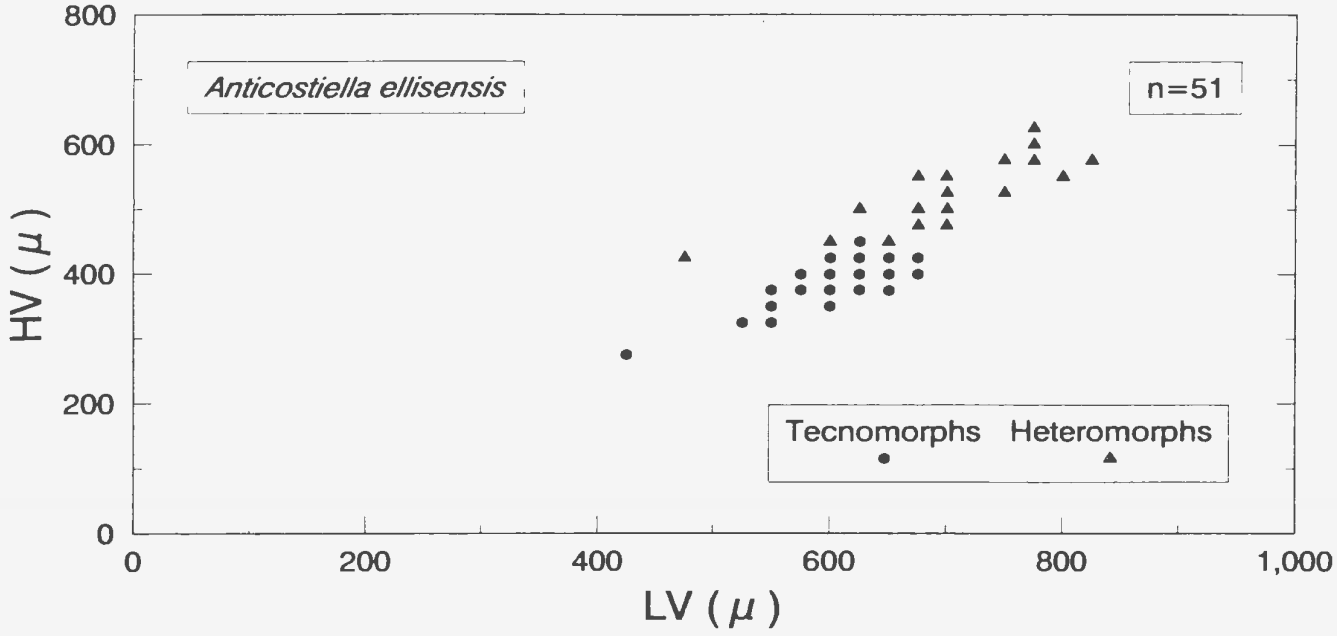
?1989 *Anticostiella reticulata* Copeland, p. 14, pl. 1, fig. 13; pl. 2, figs. 19-25.

Holotype.- *Anticostiella ellisensis* Copeland 1973, p. 9, pl. 3, fig. 24.

Diagnosis.- See Copeland (1973, p. 9).

Description.- Valves subovate in lateral view, dorsally truncate. HV at about mid-length, LV slightly above mid-height. Dorsal margin sinuous; dorsum straight and sunken between dorsal extensions of L1 and L3. Free margin broadly convex. Cardinal angles about 130°. Trilobate, L1 crescentic and concave posteriorly; L2 a discrete anteromedian node; L3 divided into a prominent dorsal knob and a posteroventral lobe. Lobes separated by furrows. Valve surface lobate in appearance. Narrow velar and free marginal ridges. Dimorphism distinctive, tecnomorphs are more elongate and less lobate than the commoner heteromorphs which have three anteroventral loculi.

Measurements.- The specimens of *Anticostiella ellisensis* only exhibit limited size variation and no instar patterns can be recognised (Text-fig. 11). It is not certain whether the specimens are adults or juveniles; heteromorphs are larger than tecnomorphs.



Text-fig. 11. Size dispersion diagram of *Anticostiella ellisensis* Copeland 1973 from samples A-7, A-9, A-10, A-11, A-14, A-15 and A-16.

Remarks.- Morphologically the genera *Bromidella* Harris 1931, *Eohollina* Harris 1957 and *Anticostiella* Copeland 1973 are similar and taxa assigned to them are, in part, synonymous. *Anticostiella* differs from *Bromidella* and *Eohollina* in the nature of its heteromorphic dimorphism. In *Anticostiella*, the heteromorph has three distinctive anteroventral loculi, while in *Bromidella* and *Eohollina* the brood pouch is elongate and undivided. These differences probably reflect environmental conditions and/or the degree of development of a specimen rather than generic or even specific level taxonomic differences. In this author's opinion the small size, nature of lobation and the presence of loculi in *Anticostiella ellisensis*, suggests that this taxon is an instar of a larger, possibly unknown species of *Tetradella*. Unfortunately, the present collections do not contain sufficient material to confirm or reject this hypothesis.

Material.- Fifty-one valves, most of them well preserved.

Occurrence.- Members 1 (A-7, A-9), 2 (A-10), 3 (A-11), 4 (A-14, A-15) and 5 (A-16), Ellis Bay Formation, Anticosti Island.

Subfamily UNCERTAIN

Genus *Tallinnella* Öpik 1937

Type species.- *Tallinnella dimorpha* Öpik 1937

Diagnosis.- See Öpik (1937, pp. 24-25), Jaanusson (1957, pp. 340-344), Kesling and Hessland *in* Moore (1961, p. Q153).

Remarks.- The genus *Tallinnella* differs from the genus *Tetradella*, in having velar rather than locular dimorphism. See Henningsmoen (1953a, pp. 213-215) for further discussion of the differences between *Tetradella* and *Tallinnella*.

Occurrence.- Known from the Lower to Upper Ordovician of Europe and central and eastern North America, (Hessland *in* Moore 1961, p. Q153).

Tallinnella? subquadrans (Ulrich 1890)

Pl. 10, figs. 1-4; text-figs. 7h, 7p.

Synonymy.-

1890	*Tetradella subquadrans* Ulrich, p. 115, text-figs. 2a-c.
1908	*Tetradella subquadrans* Ulrich; Ulrich and Bassler, pl. 39, figs. 1-3.
?1953b	*Tallinnella trident* Henningsmoen, pp. 37-38, pl. 1, fig. 1; pl. 2, figs. 1-2.
1957	*Tallinnella quebecensis* Carter, pp. 202-204, pl. 10, figs. 4a-d, (unpublished).
?1959	*Tallinnella marchia* (Krause); Sarv, pl. 10, fig. 7-10.
?1965	*Tetradella subquadrans* Ulrich; Burr and Swain, pp. 16-17, pl. 3, figs. 1-10; pl. 5, figs. 24-26.
?1965	*Tallinnella panda* Copeland, p. 19, pl. 8, figs. 28-30.
?1979a	*Tallinnella rara* Sarv; Ivanova, p. 131, pl. 10, fig. 3.

Holotype.- *Tetradella subquadrans* Ulrich 1890, p. 115, text-figs. 2a-c.

Diagnosis.- See Ulrich (1890, p. 115).

Description.- Valves subrectangular. HV at about mid-length, LV at about mid-height. Ventral margin gently curved and subparallel to straight hingeline. Anterior and posterior margins evenly rounded. Anterior and posterior cardinal angles about 120°. Quadrilobate, but only three lobes and two sulci are well developed. L1, L3 and L4 long, prominent and narrow, all extending above dorsal margin. L3 and L4 anteriorly curved in their ventral portions. L1, L3 and L4 joined by a narrow ventral connecting lobe. Short knob-like L2 merges with L1. S1, S2 and S3 shallow. Narrow, ridge-like frill extends around entire free margin. Subvelar channel shallow; free margins marked by a row of spinelets. Surface smooth. No dimorphism observed.

Measurements.- LV 1775 μ, 1675 μ, 1550 μ, 1150 μ.
HV 1000 μ, 950 μ, 875 μ, 625 μ.

Remarks.- As Schmidt (1941, p. 41) and Henningsmoen (1953a, p. 213) noted, species assigned to the genus *Tetradella* Swartz 1936 can be arranged into two groups: the *quadrilirata* group and the *subquadrans* group. Henningsmoen (1953a) restricted *Tetradella* to the loculate *quadrilirata* group and assigned the *subquadrans* group to Öpik's (1937) genus *Tallinnella*, a practice that is tentatively followed here. Apart from small differences in lobation *Tallinnella? subquadrans* is similar to *Ctenobolbina ciliata* (Emmons 1855) described herein.

Material.- Twelve valves and one carapace, only the carapace is well preserved, (Carter Collection, Redpath Museum).

Occurrence.- Trenton Group (S-8, S-12), Laval and Sorel map-areas, St. Lawrence Lowlands.

Genus *Ctenobolbina* Ulrich 1890

Type species.- *Beyrichia ciliata* Emmons 1855

Diagnosis.- See Ulrich (1890, p. 108), Henningsmoen (1953a, pp. 211-212) and Kesling *in* Moore (1961, p. Q135).

Remarks.- *Ctenobolbina* is assigned to the Family Tetradellidae here, following Warshauer and Berdan (1982, p. H29). *Ctenobolbina* is a "sack" genus to which a wide variety of unisulcate and disulcate taxa have been assigned and is badly in need of revision.

Occurrence.- Known from the Middle and Upper Ordovician of North America, (Kesling *in* Moore 1961, p. Q135).

Ctenobolbina ciliata (Emmons 1855)

Pl. 10, figs. 5-6; text-fig. 7q.

Synonymy.- 1855 *Beyrichia ciliata* Emmons, p. 219, text-fig. 74c.
?1871 *Beyrichia tumifrons* Hall, pp. 231-232, pl. 8, fig. 11.
?1875 *Beyrichia tumifrons* Hall; Hall and Whitfield, pp. 102-103, pl. 4, fig. 8.
1890b *Beyrichia ciliata* Emmons; Jones, pp. 19-20, pl. 3, figs. 12-16; pl. 4, figs. 16-18.
1890 *Ctenobolbina ciliata* (Emmons); Ulrich, pp. 108-109, pl. 7, figs. 1a-b.
1908 *Ctenobolbina ciliata* (Emmons); Ulrich and Bassler, pl. 40, figs. 1-2.
non 1911 *Ctenobolbina ciliata* (Emmons); Wade, p. 452, pl. 36, fig. 6.
1923a *Ctenobolbina ciliata* (Emmons); Ulrich and Bassler, p. 311, fig. 20, no. 4.
1924 *Ctenobolbina ciliata* (Emmons); Foerste, p. 252, pl. 45, fig. 2.
1928 *Ctenobolbina ciliata* var. *parva* Kirk, pp. 418-419, figs. 3a-c.
1934 *Ctenobolbina ciliata* (Emmons); Bassler and Kellett, p. 27, fig. 11, no. 4.
1936 *Ctenobolbina ciliata* (Emmons); Swartz, p. 551, pl. 80, fig. 1d.
?1936 *Ctenobolbina emaciata* Ulrich; Swartz, pl. 80, fig. 1b.
1944 *Ctenobolbina ciliata* (Emmons); Shimer and Shrock, p. 669, pl. 281, figs. 63-64.
?1947 *Tetradella complicata* (Salter); Harper, pp. 346-347, pl. 10, fig. 3.

?1947 *Tetradella salopiensis* Harper, pp. 351-352, pl. 10, figs. 5, 7, 9; text-fig. 1c.

?1951 *Ctenobolbina bispinosa* Ulrich; Keenan, p. 572, pl. 78, fig. 1; pl. 79, figs. 31-33.

1951 *Ctenobolbina ciliata* (Emmons); Moore, Lalicker and Fischer, p. 526, fig. 14.3, no. 1.

?1959 *Tallinnopsis iewica* (Neckaja); Sarv, pl. 13, figs. 12-13.

1961 *Ctenobolbina ciliata* (Emmons); Kesling *in* Moore, p. Q135, fig. 66.4d.

1972 *Ctenobolbina ciliata* (Emmons); Warshauer, pp. 102-111, pl. 3, figs. 1-5; pl. 4, figs. 1-3, (unpublished).

?1977 *Cerninella bohemica* (Barrande); Přibyl, p. 67, pl. 4, figs. 1-2; text-fig. 3, nos. 1-2; text-fig. 11, nos. 1-2; text-fig. 16, no. 1.

?1977 *Cerninella complicata* (Salter); Přibyl, pp. 67-68, pl. 3, figs. 1-7; text-fig. 3, nos. 3-5; text-fig. 10, no. 1; text-fig. 11, no. 4; text-fig. 16, no. 2.

?1982 *Ctenobolbina ventrispinifera* Warshauer and Berdan, pp. H29-H32, pl. 4, figs. 1-14.

?1985 *Ctenobolbina ciliata* (Emmons); Berdan and Balanc, pp. 20-21, (not figured).

Holotype.- *Beyrichia ciliata* Emmons 1855, p. 219, text-fig. 74c.

Diagnosis.- See Warshauer (1972, pp. 102-111) and Berdan and Balanc (1985, pp. 20-21).

Description.- Valves subrectangular. HV just anterior of mid-length, LV just above mid-height, WV posteromedianly. Gently curved ventral margin subparallel to straight hingeline. Anterior and posterior margins evenly rounded. Anterior and posterior cardinal angles about 120°. Quadrilobate, but only three lobes and two sulci are well developed. L1 bulbous and subrounded; L2 indistinct, merges with L1; L3 long, prominent and narrower than L1; L4 wide, low. S1 a shallow almost indistinct re-entrant at the posterodorsal margin of L1; S2 wide and deep; S3 shallow. Both S2 and S3 extend from the hingeline to the ventral margin of domicilium. Narrow velate frill or velum extends from the mid-anterior margin around the adventral

surface, to the mid-posterior margin. Subvelar channel shallow; free margins marked by a row of spinelets. Surface finely papillose.

Measurements.- LV 2225 μ, 2125 μ, 2025 μ, 1875 μ, 1750 μ.
HV 1225 μ, 1225 μ, 1150 μ, 1175 μ, 1125 μ.

Remarks.- The specimens described here as *Ctenobolbina ciliata* are probably tecnomorphs. Specimens which are suspected to be the heteromorphs of this species are described below as *Ctenobolbina* sp. The two suspected dimorphs are kept separate here, because they have not been found together and dimorphism remains unproved. Although this taxon is assigned to *Ctenobolbina* here, it could equally well be assigned to *Tallinnella* and is similar to a number of tallinnellids. Several other taxa, like *Ctenobolbina lucifer* Copeland 1965 and *Zygobolboides tuctaprariensis* Přibyl 1984 are also similar to *Ctenobolbina ciliata*.

Material.- Twelve valves and two carapaces; most of the specimens have their original shell material preserved, but some are corroded or partially broken, (Carter Collection, Redpath Museum).

Occurrence.- Tétreauville Formation (S-2), Laval map-area, St. Lawrence Lowlands.

***Ctenobolbina* sp.**

Pl. 10, fig. 7; text-fig. 7r.

Synonymy.- **1957** *Ctenobolbina obesa* Carter, pp. 221-223, pl. 11, figs. 6a-d, (unpublished).

Description.- *Ctenobolbina* sp. is like *Ctenobolbina ciliata* except that its three lobes are more swollen and its heteromorphic frill is much broader.

Measurements.- LV 1650 μ, 1600 μ, 1525 μ.
HV 1000 μ, 975 μ, 925 μ.

Remarks.- See under *Ctenobolbina ciliata*.

Material.- Eight moderately well-preserved calcified valves, (Carter Collection, Redpath Museum).

Occurrence.- Nicolet Formation (S-13), Aston map-area, St. Lawrence Lowlands.

Subfamily UNCERTAIN

Genus *Ceratopsis* Ulrich 1894

Type species.- *Beyrichia chambersi* Miller 1874

Diagnosis.- See Kesling and Hussey *in* Moore (1961, pp. Q151-Q152), Warshauer (1975, p. 445) and Vannier (1987, p. 726).

Remarks.- Definition of the genus *Ceratopsis* was originally (Ulrich 1894, p. 676) based on L-S sculpture and particularly L1, which is modified into a distinctive, dorsally directed fimbriate spine. Warshauer's (1975, p. 445) recognition that *Ceratopsis* was sexually dimorphic, led him to amend the diagnosis, to encompass only those species that exhibit "infravelar antral dimorphism". Warshauer and Berdan (1982, p. H33) used this criterion to exclude some species that were originally assigned to *Ceratopsis*. In his recent review of the genus, Vannier (1987, p. 726) concurred with Warshauer (1975) and Warshauer and Berdan (1982) by restricting *Ceratopsis* to those species with a "non-dimorphic ridge like histial flange and a variable velum which is often dimorphic". This author favours use of the older, simpler definitions of *Ceratopsis* which emphasize L-S sculpture (especially L1). Restricting *Ceratopsis* to taxa that display specific, often difficult to recognise, dimorphic characters may exclude taxa that have a fimbriate spine and have historically been termed *Ceratopsis*. Because *Ceratopsis* is such a distinctive genus, it has attracted considerable interest and in the process has become oversplit, with a number of synonymous species reflecting intraspecific variation rather than specific level differences. Species of *Ceratopsis* can be divided into two broad groups: the *chambersi* group, which is made up of species with a long, spinous speral process

(*sensu* Jaanusson 1957, p. 190) and the *oculifera* group, which contains species with a more palmate speral process.

Occurrence.- Known from the Middle and Upper Ordovician of North America and the Middle Ordovician of Britain, (Jones 1986, p. 42).

***Ceratopsis chambersi* (Miller 1874)**

Pl. 11, figs. 1-4; text-figs. 7s-u.

Synonymy.-

1874 *Beyrichia chambersi* Miller, p. 234, text-fig. 27.

?1875 *Beyrichia chambersi* Miller; Hall and Whitfield, pp. 104-105, pl. 4, figs. 11-12.

?1891 *Beyrichia quadrifida* Jones, p. 66, pl. 11, figs. 9a-b.

1894 *Ceratopsis chambersi* (Miller); Ulrich, p. 676, pl. 46, figs. 19-22.

1908 *Ceratopsis chambersi* (Miller); Ulrich and Bassler, p. 308, pl. 39, figs. 13-16.

?1908 *Ceratopsis chambersi robusta* Ulrich; Ulrich and Bassler, pl. 39, figs. 17-18.

?1908 *Ceratopsis quadrifida* (Jones); Ulrich and Bassler, pl. 39, figs. 21-22.

1919 *Ceratopsis chambersi* (Miller); Bassler, pl. 55, fig. 34.

1923a *Ceratopsis chambersi* (Miller); Ulrich and Bassler, p. 311, fig. 20, no. 5.

1934 *Ceratopsis chambersi* (Miller); Bassler and Kellett, p. 27, fig. 11, no. 5.

1936 *Ceratopsis chambersi* (Miller); Swartz, p. 552, pl. 81, fig. 4.

1944 *Ceratopsis chambersi* (Miller); Shimer and Shrock, p. 667, pl. 281, figs. 48-50.

1950 *Ceratopsis chambersi* (Miller); Levinson, pp. 69-70, text-fig. 7.

1951 *Ceratopsis chambersi* (Miller); Keenan, pl. 78, fig. 7.

1951 *Ceratopsis chambersi* (Miller); Kesling, pl. 6, figs. 7a-b.

1951 *Ceratopsis chambersi robusta* Ulrich; Kesling, pl. 6, figs. 8a-b.

1956 *Ceratopsis chambersi* (Miller); Cornell, p. 50, pl. 12, fig. 14, (unpublished).

1957 *Tetradella prostoloba* Carter, pp. 197-199, pl. 10, figs. 2a-d, (unpublished).

1957 *Ceratopsis laevicornis* Carter, pp. 205-207, pl. 10, figs. 5a-f, (unpublished).

1961 *Ceratopsis chambersi* (Miller); Kesling *in* Moore, pp. Q151-Q152, figs. 82.2a-b.

1972 *Ceratopsis chambersi* (Miller); Warshauer, pp. 117-126, pl. 5, figs. 1-7, (unpublished).

1975 *Ceratopsis chambersi* (Miller); Warshauer, pp. 445-452, pl. 1, figs. 1-7; pl. 2, figs. 1-5; pl. 3, figs. 1-6.

?1982 *Ceratopsis robusta* Ulrich; Warshauer and Berdan, p. H35, pl. 5, figs. 13-17, (re-figured holotype).

?1982 *Ceratopsis quadrifida* (Jones); Warshauer and Berdan, p. H35, pl. 5, fig. 19, (re-figured holotype).

?1985 *Ceratopsis chambersi* (Miller); Berdan and Balanc, p. 22, (not figured).

1987 *Ceratopsis chambersi* (Miller); Swain and Cornell, p. 107, pl. 3, fig. 2.

?1987 *Ceratopsis quadrifida* (Jones); Swain and Cornell, p. 107, pl. 3, figs. 3a-d; pl. 12, figs. 1-2.

1987 *Ceratopsis chambersi* (Miller); Vannier, fig. 11, no. 11.

?1988 *Ceratopsis britannica* Spjeldnaes; Siveter, pl. 1, fig. 9.

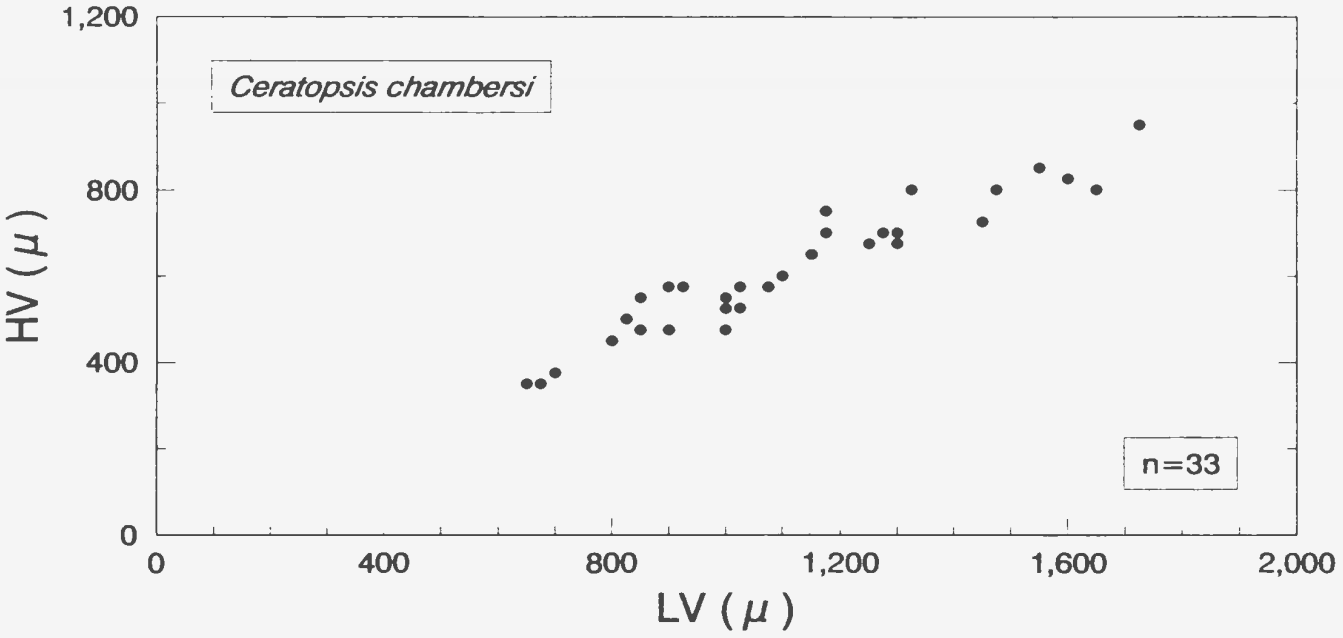
Holotype.- *Beyrichia chambersi* Miller 1874, p. 234, text-fig. 27.

Diagnosis.- See Miller (1874, p. 234), Warshauer (1972, pp. 117-126), Warshauer (1975, pp. 445-452) and Warshauer and Berdan (1982, pp. H44-H45).

Description.- Equivalved, valves subelliptical and dorsally truncate. HV anterior of mid-length, LV just above mid-height, WV mid-ventrally. Hinge line straight; anterior and posterior cardinal angles about 120°. Convex ventral margin grades into narrowly rounded posterior margin and more bluntly rounded anterior margin. Quadrilobate, prominent L1 modified into an elongate subconical fimbriate spine or speral process. Edge of process serrated into comb-like teeth. In most specimens the entire speral process is broken off. Narrow, short and posterodorsally inclined L2 does not reach dorsal margin. Long, s vollen L3 extends to dorsal margin. L4, wide and poorly defined. S1 short, narrow; S2 wide, deep; S3 shallow and poorly defined. Lobes joined ventrally by a raised histial connecting lobe. Supravelar

channel separates the ventral flange of the connecting lobe from the subparallel velar frill. Shallow subvelar channel separates narrow velar frill from the marginal rim. Surface smooth to finely granulose.

Measurements.- The specimens of *Ceratopsis chambersi* exhibit continuous size variation and no instar patterns can be recognised (Text-fig. 12).



Text-fig. 12. Size dispersion diagram of *Ceratopsis chambersi* (Miller 1874) from samples S-4, S-18 and S-19.

Remarks.- Warshauer (1975) was the first to note that *Ceratopsis chambersi* exhibits distinctive velar dimorphism, in which the more common tecnomorphs have a narrow concave velar frill, while the much rarer heteromorphs have a wide convex frill. None of the specimens in the current collections have dimorphic frills, and all are presumed to be tecnomorphs.

Material.- The Carter Collection (Redpath Museum) contains at least sixty well-preserved calcified valves, most of which have their fimbriate processes broken. Only

the five, nine and sixteen specimens from samples S-4, S-18, S-19 were examined in detail.

Occurrence.- Trenton Group at numerous localities in the Laval, Sorel, Grondines and Portneuf map-areas, St. Lawrence Lowlands, (see Carter 1957, p. 199 and p. 207 for details). Described specimens from the Deschambault Formation (S-4, S-18), Laurentides and Grondines map-areas and from the upper part of the Trenton Group (S-19), Grondines map-area, St. Lawrence Lowlands.

Ceratopsis sp.

Pl. 11, figs. 5-7; text-fig. 7v.

Synonymy.-

non 1891	*Beyrichia quadrifida* Jones, p. 66, pl. 11, figs. 9a-b.
?1934	*Ceratopsis quadrifida* (Jones); Kay, p. 340, pl. 44, fig. 27.
?1952	*Ceratopsis quadrifida* (Jones); Moore, Lalicker and Fischer, p. 525, fig. 14.2, no. 7.
1970	*Ceratopsis* sp. Copeland, p. 24, pl. 4, fig. 30.
?1974	*Ceratopsis quadrifida* (Jones); Copeland, p. 20, pl. 4, fig. 10; pl. 6, figs. 1-2; pl. 7, figs. 1-3; text-fig. 6, no. 6.
?1977a	*Ceratopsis quadrifida* (Jones); Copeland, pl. 1, fig. 4.
?1977c	*Ceratopsis quadrifida* (Jones); Copeland, pl. 2, fig. 8; pl. 5, fig. 5
non 1982	*Ceratopsis quadrifida* (Jones); Warshauer and Berdan, p. H35, pl. 5, fig. 19, (re-figured holotype).

Description.- Valves semi-ovate and preplete. HV anterior of mid-length, LV slightly above mid-height. Long, straight hinge line with cardinal angles of about 120°. Ventral, anterior and posterior margins strongly convex. Quadrilobate, L1 broad, dorsally developed into a distinctive subtriangular fimbriate spine or speral process. The speral process extends above hinge line and is obliquely oriented to the surface of the valve. L2 short, posterodorsally inclined; does not extend to hinge line. L3 a long, narrow rounded ridge that extends to dorsal margin. L4 wide, not well defined. Lobes joined ventrally. S1 narrow, straight; S2 deep, curved; S3 wide, shallow.

Valves with a well developed velar ridge along the anterior and ventral margins. Broad subvelar channel. Marginal rim poorly developed posterodorsally and concealed ventrally by velar ridge.

Measurements.- LV 1325 μ, 1275 μ.
HV 900 μ, 875 μ.

Remarks.- Unfortunately, the present collections do not contain enough material to assess whether *Ceratopsis* sp. is synonymous with any of the better known species of *Ceratopsis* that are figured by Vannier (1987, p. 740). *Ceratopsis* sp. is similar to the taxa identified as *Ceratopsis quadrifida* (Jones 1891) by Kay (1934) and Copeland (1974 and 1977c), but dissimilar to the holotype of this species that was re-illustrated by Warshauer and Berdan (1982, pl. 5, fig. 19).

Material.- Five adult and three juvenile carapaces; specimens are generally poorly preserved.

Occurrence.- Vauréal Formation (A-2), Anticosti Island.

Subfamily UNCERTAIN

Genus *Lambeodella* Copeland 1989

Type species.- *Lambeodella uniloculata* Copeland 1989

Diagnosis.- See Copeland (1989, pp. 14-15).

Occurrence.- Known from the Upper Ordovician of the Northwest Territories and Anticosti Island.

Lambeodella? sp.

Pl. 12, fig. 1; text-fig. 7w.

Description.- Valves subelliptical and dorsally truncate. HV at about mid-length, LV at about mid-height, WV posteromedianly. Dorsal margin long and straight, free

margins broadly rounded. Cardinal angles distinct, about 120°. Quadrilobate, L1 weak; L2 club-shaped; L3 and L4 joined ventrally into a large swollen crescentic lobe. L3-L4 projects above the hinge line as a distinctive node. S1 poorly developed; S2 a deep crescentic furrow; S3 undeveloped. Tecnomorphs have well developed histium and velum.

Measurements.- LV 1825 μ, 1575 μ.
HV 1050 μ, 875 μ.

Remarks.- In *Lambeodella?* sp. lobation is expressed as relatively simple, swollen ridges and sulci. This species is similar to *Lambeodella uniloculata* Copeland 1989, but without a larger collection that includes heteromorphs, it is not possible to tell whether or not they are synonymous.

Material.- One carapace, one valve and three broken valves (all presumed to be tecnomorphs); all of the specimens are somewhat corroded.

Occurrence.- Vauréal Formation (A-5, A-6), Anticosti Island.

Family UNCERTAIN

Genus *Dicranella* Ulrich 1894

Type species.- *Dicranella bicornis* Ulrich 1894

Diagnosis.- See Ulrich (1894, p. 665), Kay (1940, p. 260) and Kesling *in* Moore (1961, p. Q195).

Remarks.- Schmidt (1941) noted that *Piretella* Öpik 1937 is, at least in part, synonymous with *Dicranella.*

Occurrence.- Known from the Middle Ordovician of North America, (Kesling *in* Moore 1961, p. Q195).

Dicranella? **sp.**

Pl. 12, fig. 2; text-fig. 13a.

Synonymy.- **1957** *Dicranella* sp. Carter, pp. 181-183, pl. 9, fig. 6, (unpublished).
?1965 *Dicranella marginata* Ulrich; Copeland, pp. 49-50, pl. 11, fig. 15.
?1982 *Dicranella? marginata* Ulrich; Warshauer and Berdan, pp. H45-H46, pl. 9, figs. 5-6.
?1987 *Dicranella marginata* Ulrich; Swain and Cornell, p. 114, pl. 3, figs. 5a-b.

Description.- Valve subovate and preplete. HV anterior of mid-length, LV at hingeline. Dorsal margin straight, ventral margin evenly rounded with a distinctive anterior swing. Anterior margin evenly rounded, posterior margin bluntly subtruncate. Anterior cardinal angle about 110°, posterior cardinal angle about 100°. L2, a large distinctive presulcal subspherical node. L3 large and swollen. Narrow, slit-like, anteromedian S2. Flattened border extends around free margins. Surface of valve smooth.

Measurements.- LV 1650 μ.
HV 1075 μ.

Remarks.- *Dicranella?* sp. is tentatively assigned to *Dicranella*, but with only one specimen available, this assignment remains uncertain. Several other genera like *Piretella* Öpik 1937, *Vittella* Schallreuter 1964 and *Bullaeferum* Qvale 1980 contain species which are similar to *Dicranella?* sp.

Material.- One partially broken and distorted calcified valve, (Carter Collection, Redpath Museum).

Occurrence.- Leray Formation (S-20), St. Raymond map-area, St. Lawrence Lowlands.

Suborder BINODICOPINA Schallreuter 1972

Diagnosis.- See Schallreuter (1972, pp. 139-140) and Vannier *et al.* (1989, p. 172).

Remarks.- Binodicopids are non-dimorphic palaeocopids with comparatively few distinctive features.

Superfamily DREPANELLACEA Ulrich and Bassler 1923

(*nom. transl.* Polenova and Zanina 1960)

Diagnosis.- See Scott *in* Moore (1961, p. Q123) and Schallreuter (1972, pp. 140-141).

Remarks.- The Drepanellacea are a large diverse group of ostracodes, that exhibit continuous variation in the number and position of nodes, the degree of ornamentation and the nature of the marginal rim.

Family AECHMINIDAE Bouček 1936

(*nom. transl.* Swartz 1936)

Diagnosis.- See Levinson *in* Moore (1961, p. Q127).

Genus *Aechmina* Jones and Holl 1869

Type species.- *Aechmina cuspidata* Jones and Holl 1869

Diagnosis.- See Levinson *in* Moore (1961, p. Q127).

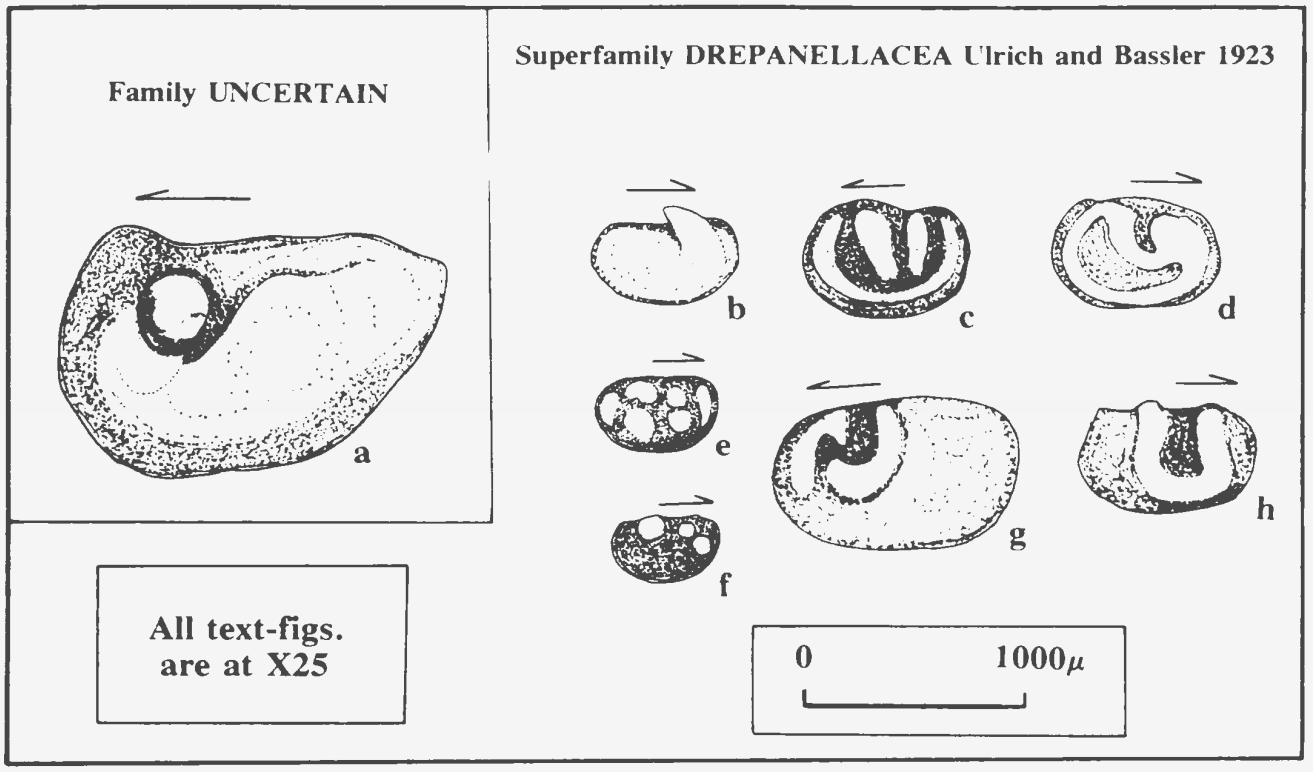
Occurrence.- Known from the Middle Ordovician to middle Mississippian of North America, Europe and Australia, (Levinson *in* Moore 1961, p. Q127).

Aechmina maccormicki Copeland 1973

Pl. 12, figs. 3-5; text-fig. 13b.

Synonymy.- ?1951 *Aechmina maquoketensis* Keenan, p. 573, pl. 79, figs. 19-20.
1973 *Aechmina maccormicki* Copeland, pp. 19-20, pl. 1, fig. 8; pl. 3, figs. 5-7.

Text-fig. 13



a. *Dicranella?* sp.
Leray Formation, St. Lawrence Lowlands, (S-20).

b. *Aechmina maccormicki* Copeland 1973
Ellis Bay Formation, Anticosti Island, (A-1).

c. *Bollia subaequata* Ulrich 1894
Deschambault Formation, St. Lawrence Lowlands, (S-15).

d. *Jonesites semilunatus* (Jones 1890)
Ellis Bay Formation, Anticosti Island, (A-7).

e. *Quasibollia persulcata* (Ulrich 1879)
Utica Group, St. Lawrence Lowlands, (S-14).

f. *Warthinia nodosa* (Ulrich 1890)
Vauréal Formation, Anticosti Island, (A-5).

g. *Jonesella obscura?*
Trenton Group, St. Lawrence Lowlands, (S-22A).

h. *Jonesella* sp.
Nicolet Formation, St. Lawrence Lowlands, (S-24).

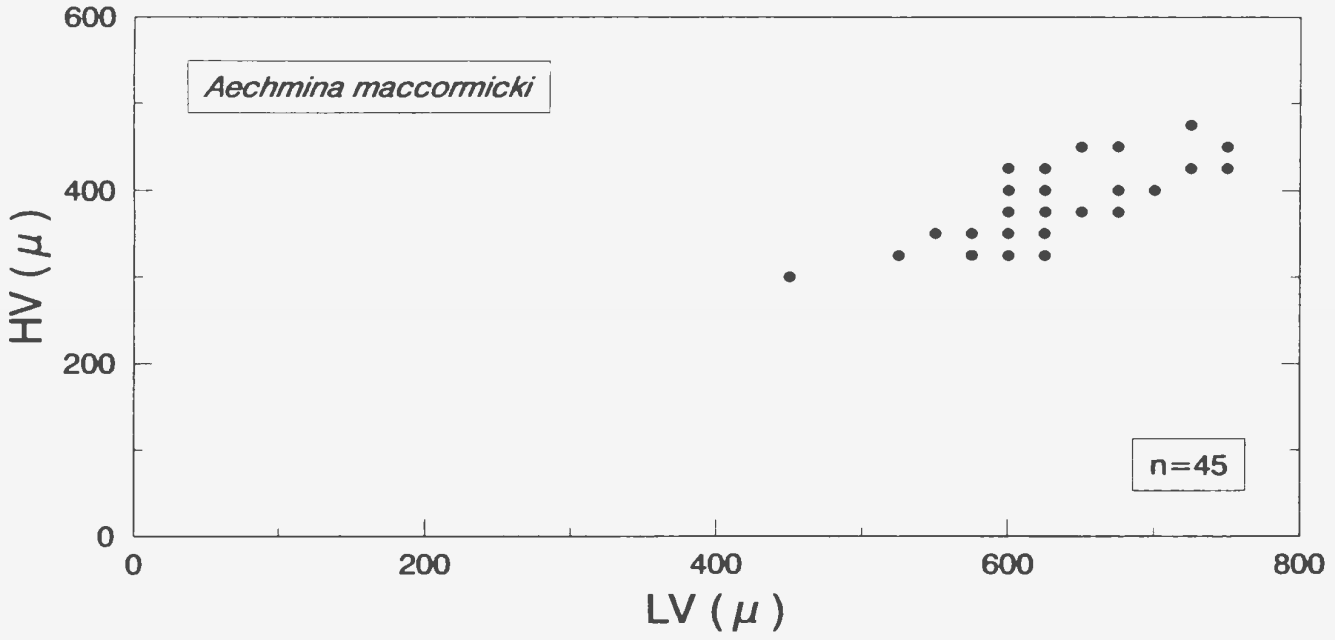
?1977 *Antiaechmina blumenstengeli* Přibyl, pp. 88-89, text-fig. 5, figs. 6-7.

Holotype.- *Aechmina maccormicki* Copeland 1973, pp. 19-20, pl. 3, fig. 6.

Diagnosis.- See Copeland (1973, pp. 19-20).

Description.- Valves subovate and dorsally truncate. HV at about mid-length, LV just above mid-height. Dorsal margin straight, free margins evenly rounded. Cardinal angles about 130°. Large, prominent anterodorsal horn-shaped spine. Spine merges with lateral surface proximally and becomes posterolaterally curved, distally. Valve swollen anteroventrally. Surface smooth.

Measurements.- The specimens of *Aechmina maccormicki* only exhibit limited size variation (Text-fig. 14). No instar patterns are recognisable and the assemblage may be size-sorted. It is not certain whether the specimens are adults and juveniles.



Text-fig. 14. Size dispersion diagram of *Aechmina maccormicki* Copeland 1973 from samples A-7 and A-9.

Remarks.- *Aechmina maccormicki* is similar to *Faurella cartieri* Copeland 1973 and both taxa were originally described from the same collections.

Material.- Thirty-eight calcified valves; all the specimens are moderately well preserved.

Occurrence.- Member 1 (A-7, A-9), Ellis Bay Formation, Anticosti Island.

Family BOLLIIDAE Bouček 1936

(*nom. transl.* Scott and Wainwright *in* Moore 1961)

Diagnosis.- See Scott and Wainwright *in* Moore (1961, p. Q127), Guber (1962, pp. 52-53) and Jones (1987, p. 77).

Genus *Bollia* Jones and Holl 1886

Type species.- *Bollia bicollina* Jones and Holl 1886 has been designated the new type species of the genus *Bollia* by the International Commission on Zoological Nomenclature (see Guber 1968, pp. 360-363 and Melville 1970, pp. 169-170).

Diagnosis.- See Bassler and Kellett (1934, p. 17) and Scott and Wainwright *in* Moore (1961, p. Q128).

Remarks.- Ulrich (1894, pp. 668-669) listed the species that he considered to belong in the genus *Bollia*.

Occurrence.- Known from the Middle Ordovician to Lower Devonian of Europe and North America, (Scott and Wainwright *in* Moore 1961, p. Q128).

Bollia subaequata Ulrich 1894

Pl. 12, fig. 6; text-fig. 13c.

Synonymy.-
- **1894** *Bollia subaequata* Ulrich, p. 669, pl. 46, figs. 26-29.
- 1934 *Bollia subaequata* Ulrich; Kay, pp. 336-337, pl. 44, figs. 6-16.
- 1940 *Bollia subaequata* Ulrich; Kay, p. 258, pl. 32, fig. 32.
- 1944 *Bollia subaequata* Ulrich; Shimer and Shrock, p. 667, pl. 281, figs. 24-26.
- 1952 *Bollia subaequata* Ulrich; Moore, Lalicker and Fischer, p. 526, fig. 14.3, no. 15.

1956 *Bollia subaequata* Ulrich; Cornell, p. 68, pl. 15, figs. 10-14, (unpublished).

1957 *Bollia subaequata* Ulrich; Carter, pp. 178-180, pl. 9, figs. 4a-c, (unpublished).

1961 *Bollia subaequata* Ulrich; Scott and Wainwright *in* Moore, p. Q128, figs. 62.3a-b.

1977 *Bollia subaequata* Ulrich; Swain, fig. 3, no. 4.

1987 *Bollia subaequata* Ulrich; Swain and Cornell, p. 105, pl. 2, figs. 1a-h.

Holotype.- *Bollia subaequata* Ulrich 1894, p. 669, pl. 46, figs. 26-29.

Diagnosis.- See Ulrich (1894, p. 669), Kay (1934, pp. 336-337) and Swain and Cornell (1987, p. 105).

Description.- Valve subovate. HV at about mid-length, LV at about mid-height. Dorsal margin sinuous, free margins evenly rounded. Sunken lateral surface, bordered by sharply raised and rounded marginal rim. Lateral surface with two distinctive subequal and subvertical lobate ridges. Lobes project slightly above dorsal margin and are ventrally discontinuous. Subvertical, anteromedian sulcal furrow separates lobes. Surface smooth.

Measurements.- LV 700 μ.
HV 500 μ.

Remarks.- Lack of material precludes an in depth study of this taxon. The small size and immature morphology of *Bollia subaequata*, suggests it may be an instar of some larger and presently unknown taxon. *Lardeuxella bussacensis* (Jones 1853), as illustrated by Vannier (1985, pl. 2, fig. 4), is similar to *Bollia subaequata*.

Material.- One well-preserved calcified valve, (Carter Collection, Redpath Museum).

Occurrence.- Lower Deschambault Formation (S-15), Grondines map-area, St. Lawrence Lowlands.

Genus *Jonesites* Coryell 1930

Type species.- *Primitia excavata* Jones and Holl 1869

Diagnosis.- See Scott and Wainwright *in* Moore (1961 p. Q129).

Occurrence.- Known from the Upper Ordovician to Middle Silurian of Europe and North America, (Scott and Wainwright *in* Moore 1961 p. Q129).

***Jonesites semilunatus* (Jones 1890)**

Pl. 12, figs. 7-8; text-fig. 13d.

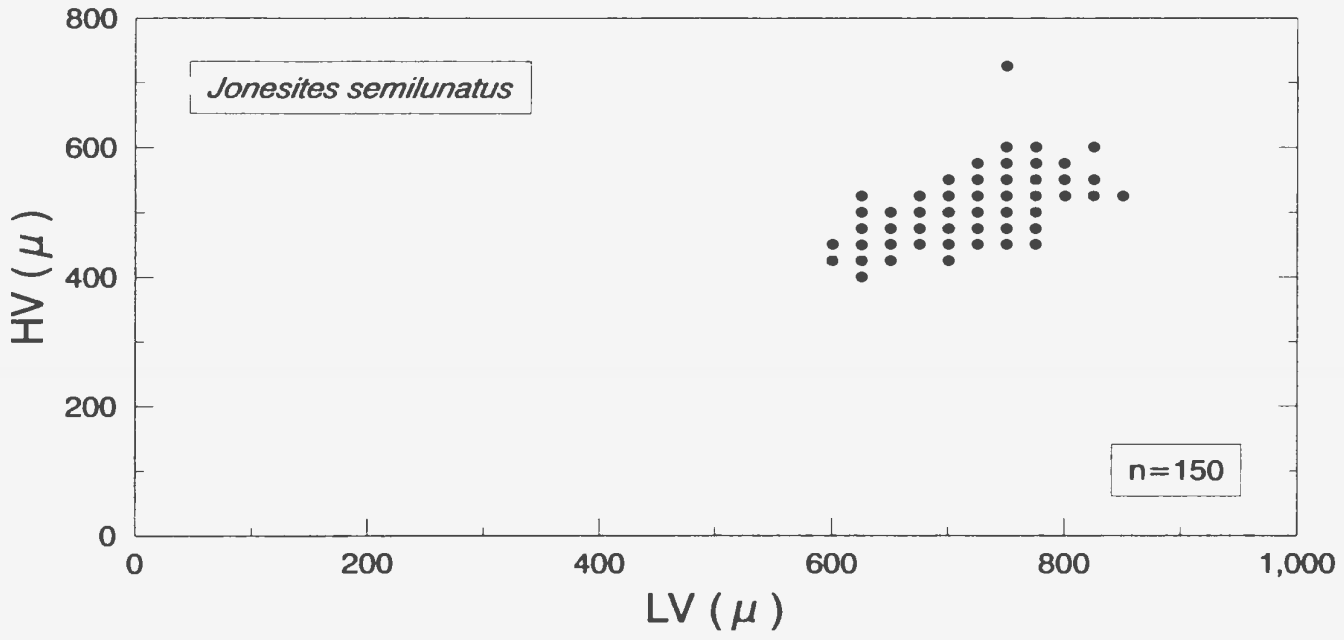
Synonymy.- ?1869 *Primitia excavata* Jones and Holl, p. 222, pl. 15, figs. 10a-c.
?1886a *Placentula excavata* (Jones and Holl); Jones and Holl, pp. 407-408, pl. 13, figs. 10-12, 16.
1890a *Bollia semilunata* Jones, p. 548, pl. 21, figs. 9a-b.
?1923a *Placentula excavata* (Jones and Holl); Ulrich and Bassler, fig. 15, no. 13.
?1928 *Bollia semilunata* Jones; Bassler *in* Twenhofel 1928, p. 346, (not figured).
?1934 *Jonesites (Placentula) excavata* (Jones and Holl); Bassler and Kellett, p. 17, fig. 6, no. 12.
?1936 *Jonesites excavatus* (Jones and Holl); Swartz, pl. 79, fig. 10.
?1948 *Jonesites excavata* (Jones and Holl); Wright, pl. 4, fig. 3, (unpublished).
?1961 *Jonesites primitia excavata* (Jones and Holl); Scott and Wainwright *in* Moore, p. Q129, fig. 62.14.
1970 *Jonesites semilunatus* (Jones); Copeland 1970, pp. 19-20, pl. 4, fig. 10; pl. 5, fig. 14.
1973 *Jonesites semilunatus* (Jones); Copeland 1973, pl. 1, figs. 16-19; pl. 8, figs. 1-2; pl. 9, fig. 14.
1977 *Jonesites semilunatus* (Jones); Copeland, p. 11, pl. 1, fig. 20.
?1978 *Jonesites excavata* (Jones and Holl); Siveter, p. 80, pl. 6, figs. 7-8.

Holotype.- *Bollia semilunata* Jones 1890a, p. 548, pl. 21, figs. 9a-b.

Diagnosis.- After Jones (1890a, p. 548) and Copeland (1970, pp. 19-20). *Jonesites* with a distinctive S2, defined by a raised U-shaped ridge that is continuous with the marginal rim. Depressed surface within the marginal rim may be reticulate.

Description.- Valves subovate and slightly postplete. HV posterior of mid-length, LV at mid-height. Dorsal and ventral margins slightly convex; anterior and posterior margins evenly rounded. Hinge sunken, cardinal angles about 140°. Submarginal ridge along contact margin. Broad rounded rim or ridge encloses the entire lateral surface. Distinctive, posteromedian, reverse comma-shaped sulcus outlined by a U-shaped extension of the marginal ridge. Depressed crescentic area (usually sediment filled), within marginal rim. Channelled marginal surface around free edge.

Measurements.- All the specimens of *Jonesites semilunatus* are roughly the same size (Text-fig. 14). No instar patterns are recognisable and the assemblage is almost certainly size-sorted.



Text-fig. 15. Size dispersion diagram of *Jonesites semilunatus* (Jones 1890) from sample A-7.

Remarks.- Although *Jonesites excavata* (Jones and Holl 1869) has a less depressed, more reticulate lateral surface within its marginal rim than *Jonesites semilunatus* (Jones 1890), the two species are morphologically similar and are probably

synonymous. Copeland (1973) designated *Jonesites semilunatus* the zone ostracode for the Upper Ordovician on Anticosti Island, because it is easily recognised and occurs throughout the Vauréal and Ellis Bay formations.

Material.- Thirty-eight carapaces and at least four hundred valves; all the specimens have their original shell material preserved.

Occurrence.- Vauréal Formation (A-2, A-3, A-4, A-8) and Members 1 (A-7, A-9), 2 (A-10, A-13), 3 (A-11), 4 (A-14, A-15) and 5 (A-16), Ellis Bay Formation, Anticosti Island.

Genus *Quasibollia* Warshauer and Berdan 1982

Type species.- *Beyrichia persulcata* Ulrich 1879

Diagnosis.- See Warshauer and Berdan (1982, pp. H19-H20).

Remarks.- Warshauer and Berdan (1982, pp. H19-H20) established *Quasibollia* for subquadrate bolliids, in which L3 is divided into a lobe and dorsal knob.

Occurrence.- Known from the Middle to Upper Ordovician of central North America, (Warshauer and Berdan 1982).

Quasibollia persulcata (Ulrich 1879)

Pl. 12, fig. 9; text-fig. 13e.

Synonymy.-

1879 *Beyrichia persulcata* Ulrich, p. 12, pl. 7, fig. 6.

?1890b *Beyrichia buchiana* Jones, p. 16, pl. 3, fig. 25.

1890 *Bollia persulcata* (Ulrich); Ulrich, p. 116, text-figs. 3a-d.

?1908 *Bollia persulcata* (Ulrich); Ulrich and Bassler, p. 288, (not figured).

?1934 *Bollia persulcata* (Ulrich); Bassler and Kellett, p. 218, (not figured).

1951 *Bollia persulcata* (Ulrich); Keenan, p. 564, pl. 78, figs. 2-3.

?1951 *Bollia ridicula* Keenan, pp. 568-569, pl. 79, figs. 34-37.

1956 *Bollia persulcata* (Ulrich); Cornell, p. 67, pl. 13, figs. 2-3, (unpublished).

1957 *Bollia persulcata* (Ulrich); Carter, pp. 177-178, pl. 9, figs. 5a-b, (unpublished).

1962 *Bollia persulcata* (Ulrich); Guber, pp. 54-56, pl. 1, figs. 3a-b, 4, (unpublished).

?1965 *Bollia persulcata* (Ulrich); Copeland, p. 8, pl. 11, figs. 9, 11.

1972 *Bollia persulcata* (Ulrich); Warshauer, pp. 50-57, pl. 1, figs. 1-5, (unpublished).

1982 *Quasibollia persulcata* (Ulrich); Warshauer and Berdan, pp. H20-H21, pl. 1, figs. 2, 4-10.

?1982 *Quasibollia copelandi* Warshauer and Berdan, pp. H21-H23, pl. 1, fig. 1.

?1982 *Quasibollia?* sp. Warshauer and Berdan, p. H23, pl. 1, fig. 11.

?1985 *Quasibollia persulcata* (Ulrich); Berdan and Balanc, pp. 15-16, (not figured).

1987 *Quasibollia persulcata* (Ulrich); Swain and Cornell, p. 105, pl. 1, figs. 6a-d.

Holotype.- *Beyrichia persulcata* Ulrich 1879, p. 12, pl. 7, fig. 6. Because of uncertainty over which of Ulrich's (1879) type specimens was the holotype, Warshauer and Berdan (1982, pp. H20-H21) designated a lectotype for this species.

Diagnosis.- See Guber (1962, pp. 54-56), Warshauer (1972, p. 50) and Warshauer and Berdan (1982, p. H20).

Description.- Valves subquadrate. HV at about mid-length, LV at about mid-height. Dorsal margin slightly arched, ventral margin broadly curved. Anterior margin more bluntly rounded than posterior margin. Rounded marginal rim that is only prominent, anteriorly and posteriorly. Sharply raised lateral surface, with two subequal and subvertical rounded lobes. Each lobe divided in half by a transverse furrow. Surface smooth to finely granulose.

Measurements.- LV 525 μ, 400 μ, 350 μ.
HV 350 μ, 250 μ, 225 μ.

Remarks.- The small size and poorly developed morphologies of the specimens suggest they are instars.

Material.- Five well-preserved calcified valves, (Carter Collection, Redpath Museum).

Occurrence.- Upper Trenton Group (S-22B) and Utica Group (S-14), Verchères map-area, St. Lawrence Lowlands.

Genus *Warthinia* Spivey 1939

Type species.- *Primitia nodosa* Ulrich 1890

Diagnosis.- After Warshauer and Berdan (1982, p. H23). Palaeocopid ostracodes with two, three or four nodes, two of which are along the hingeline. Posterior dorsal node (which may be spinose), larger than anterior dorsal node. Additional nodes, if developed are located anteriorly and/or anteroventrally. Low velar ridge parallels free margin. Valve surface, including nodes, finely reticulate.

Remarks.- The genera *Ulrichia* Jones 1890 and *Warthinia* Spivey 1939 are in part, synonymous. Spivey (1939, p. 167) established *Warthinia* for *Ulrichia*-like taxa, that have more than two nodes. More recently, Warshauer and Berdan (1982) broadened Spivey's diagnosis, to encompass taxa with only two nodes, thus making the diagnoses of *Warthinia* and *Ulrichia* even more similar. Warshauer and Berdan (1982, p. H23) recognise some ornamental differences between the Ordovician genus *Warthinia* and the Siluro-Devonian genus *Ulrichia*, which they consider significant enough to retain *Warthinia* as a separate genus. This author follows Warshauer and Berdan (1982) in accepting *Warthinia*, simply because it is not possible to assess the extent to which *Warthinia* and *Ulrichia* are synonymous, until *Ulrichia* is revised. See Guber (1962, pp. 56-59) and Warshauer (1972, p. 58) for further discussion of *Warthinia*.

Occurrence.- Known primarily from the Middle and Upper Ordovician of central and eastern North America, (Warshauer and Berdan, 1982).

***Warthinia nodosa* (Ulrich 1890)**

Pl. 12, figs. 10-11; text-fig. 13f.

Synonymy.- **1890** *Primitia nodosa* Ulrich, p. 134, pl. 10, figs. 11a-b, 12a-b.
?1890 *Ulrichia nodosa* (Ulrich); Ulrich, p. 203, (not figured).
?1928 *Ulrichia nodosa* (Ulrich); Bassler *in* Twenhofel, p. 345, (not figured).
1939 *Warthinia nodosa* (Ulrich); Spivey, p. 167, pl. 21, figs. 3-6.
1940 *Kiesowia verrucosa* Kay, p. 260, pl. 32, figs. 39-40.
?1941 *Ulrichia nodosa* (Ulrich); Schmidt, p. 57, (not figured).
1941 *Ulrichia nodosa paupera* (Ulrich); Schmidt, p. 57, pl. 4, figs. 30-31.
?1946 *Ulrichia reticulata* Thorslund, pp. 365-366, pl. 20, figs. 11a-b.
1951 *Kiesowia nodosa* (Ulrich); Keenan, p. 569, pl. 78, fig. 6.
1951 *Kiesowia verrucosa* Kay; Keenan, pp. 569-570, pl. 79, figs. 4-6.
1951 *Kiesowia binoda* Keenan, p. 570, pl. 79, figs. 2-3.
?1951 *Kiesowia insolens* Keenan, p. 570, pl. 79, fig. 1.
1956 *Kiesowia verrucosa* Kay; Cornell, p. 43, pl. 14, figs. 5a-b, (unpublished).
1957 *Kiesowia insolens* Keenan; Carter, pp. 184-185, pl. 9, figs. 7a-b, (unpublished).
1961 *Ulrichia nodosa* (Ulrich); Scott and Wainwright *in* Moore, p. Q131, figs. 62.6a-b.
1962 *Warthinia nodosa* (Ulrich); Guber, pp. 56-62, pl. 1, figs. 5a-c, 6, 7, (unpublished).
1965 *Ulrichia nodosa* (Ulrich); Burr and Swain, p. 14, pl. 4, figs. 2a-b, 3.
1965 *Ulrichia saccula* Burr and Swain, p. 15, pl. 4, figs. 4-5, 8.
1970 *Ulrichia nodosa* (Ulrich); Copeland, p. 18, pl. 4, figs. 3-4.
1972 *Warthinia nodosa* (Ulrich); Warshauer, pp. 58-66, pl. 1, figs. 6-9, (unpublished).
1977 *Ulrichia paupera* (Schmidt); Přibyl, p. 144, pl. 7, figs. 14-15; text-fig. 3, no. 11.
1982 *Warthinia nodosa* (Ulrich); Warshauer and Berdan, pp. H23-26, pl. 1, figs. 12-21; pl. 2, figs. 9-11.
?1985 *Warthinia nodosa* (Ulrich); Berdan and Balanc, p. 16, (not figured).

1987 *Kiesowia? verrucosa* Kay; Swain and Cornell, pp. 107-108, pl. 5, figs. 4a-b.

Holotype.- *Primitia nodosa* Ulrich 1890, p. 134, pl. 10, figs. 11a-b, 12a-b.

Diagnosis.- See Warshauer and Berdan (1982, p. H.23).

Description.- Valves subelliptical and amplete. HV at mid-length, LV slightly above mid-height. Dorsal margin straight to slightly arched, free margins evenly rounded. Cardinal angles about 130°. Three or four distinctive, rounded nodes developed on lateral margin. Posterodorsal node larger than other anterior nodes. Prominent velar ridge around entire free margin. Contact margin rimmed. Valve surface and nodes finely reticulate.

Measurements.- LV 775 μ, 475 μ, 475 μ, 475 μ, 450 μ, 400 μ.
HV 450 μ, 325 μ, 300 μ 300 μ, 275 μ, 275 μ.

Remarks.- Noding in *Warthinia nodosa* is highly variable, and probably reflects environmentally influenced intraspecific variation rather than real taxonomic differences. The taxa described as *Kiesowia* by Kay (1940, p. 260) and Keenan (1951, pp. 569-570), do not resemble previously described species of *Kiesowia*, and are included in synonymy with *Warthinia nodosa* here. Some European taxa, like *Ulrichia bicornis* (Jones 1855) as figured by Siveter (1978a, p. 52, pl. 3, figs. 9-10) and *Ulrichia? mayensis* Vannier 1986 as figured by Vannier (1986a, pl. 5, fig. 1) are morphologically similar to, but not synonymous with *Warthinia nodosa*. Although there is no direct evidence, the small size and highly variable noding of *Warthinia nodosa*, suggests that many of the taxa described as *Warthinia nodosa* are instars of some larger unknown species.

Material.- Ten valves, most, if not all of which are instars.

Occurrence.- Vauréal Formation (A-1, A-4, A-5), Anticosti Island.

Family RICHINIDAE Scott 1961

Diagnosis.- See Scott *in* Moore (1961, pp. Q131-Q132), Warshauer (1972, pp. 73-74) and Warshauer and Berdan (1982, pp. H27-H28).

Genus *Jonesella* Ulrich 1890

Type species.- *Leperditia crepidiformis* Ulrich 1879

Diagnosis.- See Ulrich (1890, p. 121), Moore (1961, p. Q132) and Warshauer (1972, pp. 74-75).

Remarks.- In the *Treatise* (Moore 1961, p. Q132), *Jonesella* was considered to be of uncertain affinities. More recently, Warshauer and Berdan (1982, p. H28) assigned *Jonesella* to the Richinidae, a practice that is followed here. When Ulrich (1890) established the genus *Jonesella*, he noted that it was closely allied to the existing genus *Bollia* Jones and Holl 1886. *Jonesella* however, lacks the marginal rim which is so distinctive of species assigned to *Bollia*. A number of the species originally included in *Jonesella* by Ulrich (1890 and 1894), have subsequently been assigned to other genera like *Vogdesella* Baker 1924, *Cincinnaticoncha* Warshauer 1981 and *Satiellina* Vannier 1986a.

Occurrence.- Known from the Middle to Upper Ordovician of Europe and North America, (Moore (1961, p. Q132).

Jonesella obscura? Ulrich 1894

Pl. 13, fig. 1; text-fig. 13g.

Synonymy.- **?1894** *Jonesella obscura* Ulrich, p. 668, pl. 44, figs. 17-19.
?1915 *Jonesella obscura* Ulrich; Bassler, p. 680, (not figured).
?1940 *Bollia simplex* (Ulrich); Kay, p. 258, pl. 32, figs. 33-34.
1957 *Jonesella obscura* Ulrich; Carter, pp. 212-213, pl. 11, figs. 2a-c, (unpublished).
1957 *Jonesella bilobata* Carter, pp. 209-210, pl. 11, figs. 1a-d, (unpublished).

Holotype.- *Jonesella obscura* Ulrich 1894, p. 668, pl. 44, figs. 17-19.

Diagnosis.- See Ulrich (1894, p. 668) and Carter (1957, p. 212).

Description.- Valves subelliptical to subquadrate. HV at about mid-length, LV at about mid-height. Dorsal margin nearly straight, ventral margin convex; anterior and posterior margins bluntly rounded. Cardinal angles rounded. Distinctive, anterodorsal, sharply raised and horizontally disposed S-shaped lobe. S-shaped lobe outlines depressed S1 and S2. Surface smooth to finely granulose.

Measurements.- LV 1025 μ, 475 μ.
HV 625 μ, 300 μ.

Remarks.- The current specimens are only tentatively assigned to *Jonesella obscura?*, because lobation is more pronounced than in Ulrich's (1894) holotype. Apart from its less developed sulcation, *Eoprimitia quadrata* Harris 1957, is otherwise similar to *Jonesella obscura?*.

Material.- Two well-preserved calcified valves with some original shell material preserved, (Carter Collection, Redpath Museum).

Occurrence.- Trenton Group (S-22A, S22C), Verchères map-area, St. Lawrence Lowlands.

***Jonesella* sp.**

Pl. 13, fig. 2; text-fig. 13h.

Synonymy.- ?1924 *Jonesella crepidiformis* (Ulrich); Foerste, p. 254, pl. 45, fig. 7.
1957 *Jonesella centralis* Carter, pp. 210-212, pl. 10, figs. 6a-e, (unpublished).
1972 *Jonesella turnida* Warshauer, pp. 85-89, pl. 1, figs. 14-17, (unpublished).
?1985 *Jonesella* sp. A Berdan and Balanc, pp. 18-19, (not figured).

Description.- Valves subovate and dorsally truncate. HV at about mid-length, LV at about mid-height. Dorsal margin straight, free margins evenly rounded. Anterior cardinal angle about 130°, posterior cardinal angle about 120°. Large, sharply raised

U-shaped lobe dominates anterior portion of lateral surface. Lobe subquadrate in cross-section. Anterior limb of lobe (L1), more swollen than L2. Rounded extremities of L1 and L2 project above dorsal margin. U-shaped lobe surrounds and outlines deeply sunken S2. Surface of valve smooth to finely granulose.

Measurements.- LV 800 μ, 725 μ.
HV 525 μ, 500 μ.

Remarks.- *Jonesella* sp. is synonymous with *Jonesella centralis* Carter 1957 and *Jonesella tumida* Warshauer 1972, but is not assigned to either of these species, because they are unpublished and consequently invalid. The current collections are not large enough to justify the establishment of a new specific name for *Jonesella* sp. Warshauer (1972, pp. 85-89) split *Jonesella tumida* from *Jonesella crepidiformis* (Ulrich 1879), because both adults and instars of *Jonesella tumida* have a more swollen and central U-shaped lobe than specimens of *Jonesella crepidiformis*. Comparative illustrations of *Jonesella crepidiformis* can be seen in Bassler and Kellett (1934, p. 19, fig. 6, no. 13), Moore (1961, p. Q132, fig. 64.2.) and Warshauer (1972, pp. 75-80, pl. 1, figs. 11-13). *Jonesella* sp. is very similar to the Devonian species *Bollia ungula* Jones 1889 as figured by Ulrich (1890, pl. 14, figs. 6a-b).

Material.- Three well-preserved calcified valves, (Carter Collection, Redpath Museum).

Occurrence.- Lower part of the Nicolet Formation (S-23, S-24), Verchères and Trois Rivières map-areas, St. Lawrence Lowlands.

Suborder LEIOCOPA Schallreuter 1973

Diagnosis.- See Schallreuter (1973b, p. 48) and Vannier *et al.* (1989, p. 173).

Remarks.- Leiocopes are generally smooth or punctate, lack any L-S sculpture and are often slightly umbonate (Vannier *et al.* 1989, p. 173). Vannier (1990) has recently reviewed the functional morphology and mode of life of the leiocopes.

Superfamily APARCHITIACEA Jones 1901

Diagnosis.- See Schallreuter (1973b, p. 48).

Family APARCHITIDAE Jones 1901

Diagnosis.- See Henningsmoen (1953a, pp. 230-231, p. 263) and Hessland *in* Moore (1961, pp. Q170-Q171).

Genus *Aparchites* Jones 1889

Type species.- *Aparchites whiteavesi* Jones 1889

Diagnosis.- See Hessland *in* Moore (1961, p. Q171) and Swain, Cornell and Hansen (1961, p. 351).

Remarks.- *Aparchites* is a "sack" genus, to which a wide variety of smooth, non-sulcate Lower Paleozoic ostracodes have been assigned (Schallreuter 1988). Thus, a number of taxa have been grouped in *Aparchites*, more for taxonomic convenience, than for any natural affinity. Untangling and deciphering "sack" genera like *Aparchites* is beyond the scope of this study, since it would involve extensive re-examination of holotypes (if available) and re-collection of type localities. Schallreuter (1973) discussed the probable synonymy of *Aparchites* and *Hyperchilarina* Harris 1957. Several other genera, like *Oepikella* Thorslund 1940, *Saccelatia* Kay 1940 and *Tvaerenella* Jaanusson 1957 include taxa that are similar to some of the species of *Aparchites*.

Occurrence.- Known from the Lower Ordovician to Middle Devonian of Europe, North America, Australia and Asia, (Hessland *in* Moore (1961, p. Q171).

Aparchites fimbriatus (Ulrich 1892)

Pl. 13, figs. 3-6; text-fig. 16a.

Synonymy.- **1892** *Leperditia fimbriata* Ulrich, p. 268, pl. 9, figs. 34-36.

Text-fig. 16

a. *Aparchites fimbriatus* (Ulrich 1892)
Montréal Formation, St. Lawrence Lowlands, (S-6).

b. *Aparchites* sp.
Table Point Formation, western Newfoundland, (T-4 and T-5).

c. *Saccelatia arrecta* (Ulrich 1894)
Lourdes Formation, western Newfoundland, (L-8).

d. *Schmidtella sublenticularis* (Jones 1890)
Ellis Bay Formation, Anticosti Island, (A-16).

e. *Schmidtella* sp.
Lourdes Formation, western Newfoundland, (L-9).

f. *Schmidtella* sp.
Lourdes Formation, western Newfoundland, (L-10).

g. *Leperditella rex* (Coryell and Schenck 1941)
Table Point Formation, western Newfoundland, (T-4 and T-5).

h. *Leperditella rex* (Coryell and Schenck 1941)
Table Point Formation, western Newfoundland, (T-4 and T-5).

i. *Leperditella* sp. 1
Deschambault Formation, St. Lawrence Lowlands, (S-11).

j. *Ectoprimitla?* sp.
Lourdes Formation, western Newfoundland, (L-9).

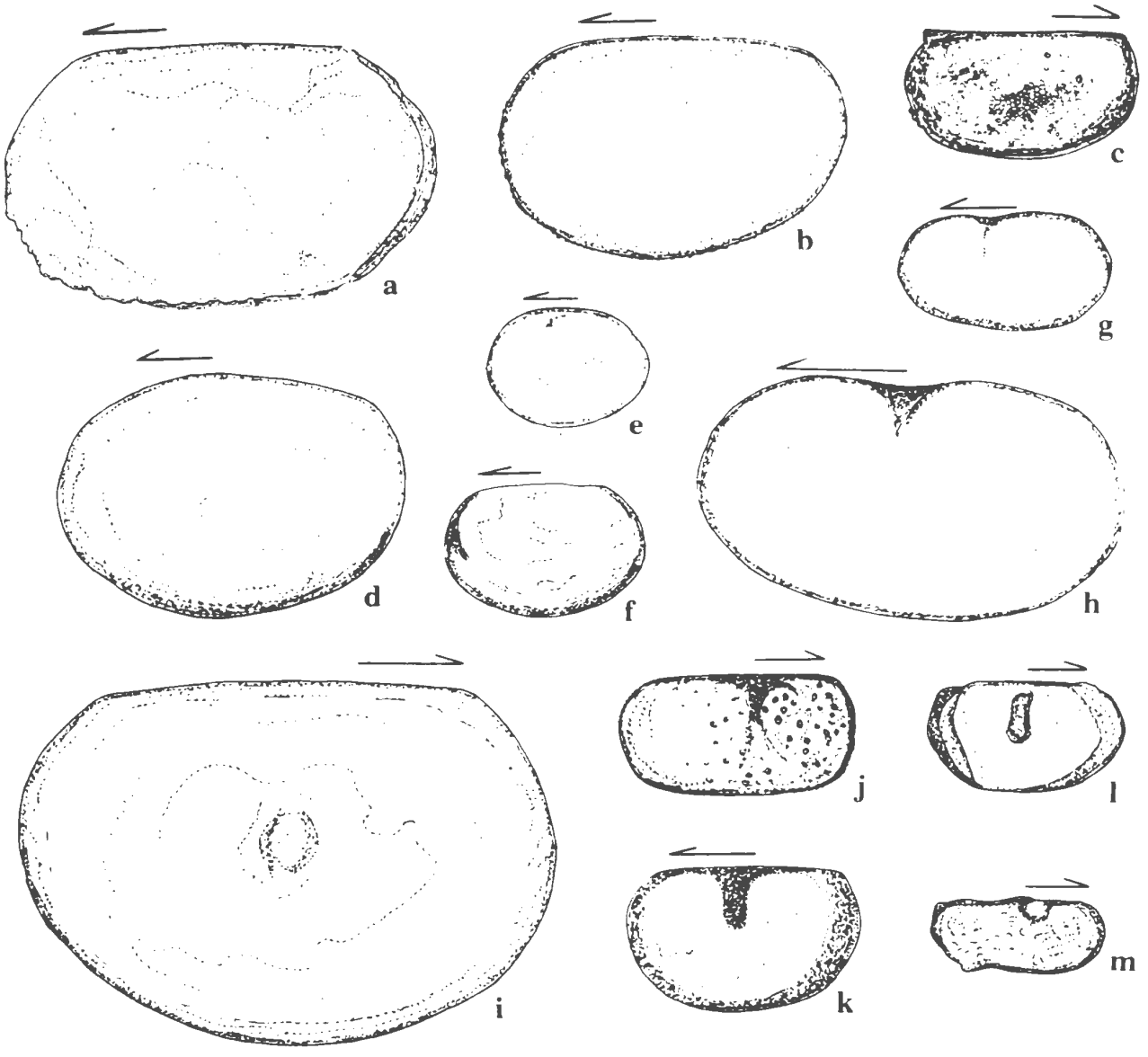
k. *Hallatia particylindrica* Kay 1934
Deschambault Formation, St. Lawrence Lowlands, (S-18).

l. *Hallatia canadensis* (Bassler 1928)
Ellis Bay Formation, Anticosti Island, (A-16).

m. *Eocytherella?* sp.
Lourdes Formation, western Newfoundland, (L-9).

Text-fig. 16

Superfamily APARCHITIACEA Jones 1901 and
Superfamily LEPERDITELLACEA Ulrich and Bassler 1906



All text-figs.
are at X25

0 1000μ

?1894 *Leperditella canalis* Ulrich, p. 637, pl. 43, figs. 1-3.

?1894 *Aparchites ellipticus* Ulrich, p. 644, pl. 43, figs. 15-17.

1894 *Aparchites fimbriatus* (Ulrich); Ulrich, p. 645, pl. 45, figs. 10-12.

?1903 *Leperditella ornata* Weller, p. 209, pl. 13, figs. 13-15.

?1940 *Aparchites carinatus* Kay, p. 244, pl. 29, figs. 29-32.

?1951 *Aparchites barbatus* Keenan, p. 562, pl. 78, figs. 19-20.

1956 *Aparchites fimbriatus* (Ulrich); Cornell, p. 30, pl. 5, figs. 1-2, (unpublished).

1957 *Leperditella ornata* Weller; Carter, pp. 78-80, pl. 3, figs. 3a-d, (unpublished).

?1957 *Aparchites kauffmanensis* Swain, p. 560, pl. 61, fig. 11; pl. 62, fig. 9.

1957 *Aparchites fimbriatus* (Ulrich); Swain, pp. 560-561, pl. 61, figs. 13a-e.

?1957 *Aparchites maccoyii* (Salter); Harris, pp. 138-140 *pars*, pl. 2, figs. 2a-c, 3a-b, *non* fig. 4.

1957 *Hyperchilarina nodosimarginata* Harris, pp. 144-145, pl. 5, figs. 16a-c.

1957 *Hyperchilarina ovata* Harris, pp. 145-146, pl. 5, figs. 17a-b.

?1957 *Hyperchilarina symmetrica* Harris, p. 147, pl. 5, figs. 18a-b.

1961 *Aparchites fimbriatus* (Ulrich); Swain, Cornell and Hansen, pp. 351-353, pl. 46, figs. 1a-h; text-fig. 2a.

?1961 *Aparchites ellipticus* Ulrich; Swain, Cornell and Hansen, p. 353, pl. 46, figs. 2a-b, 3a-b; text-fig. 2b.

?1961 *Aparchites macrus* (Ulrich); Swain, Cornell and Hansen, pp. 353-354, pl. 46, fig. 4.

1961 *Aparchites fimbriatus* (Ulrich); Hessland *in* Moore, p. Q171, figs. 108.2f-h, figs. 109.1a-f.

1962 *Aparchites fimbriatus* (Ulrich); Kraft, pp. 28-29, pl. 2, figs. 1-11; pl. 3, fig. 3; text-figs. 7a-e.

?1962 *Aparchites ellipticoides* Kraft, pp. 30-31, pl. 3, figs. 4-6; text-fig. 7k.

?1962 *Aparchites suborbicularis* Kraft, p. 31, pl. 3, figs. 7-13; text-figs. 7i-j.

?1965 *Aparchites fimbriatus?* (Ulrich); Copeland, pp. 29-30, pl. 2, figs. 5, 13.

?1965 *Aparchites? labellosus* (Jones); Copeland, p. 30, pl. 7, figs. 19-21.

?1967 *Conchoprimitia sibirica* Kanygin, pp. 13-14, pl. 1, figs. 1-1b.

1970 *"Aparchites" fimbriatus* (Ulrich); Copeland, p. 23, pl. 4, fig. 28.

1974 *"Aparchites" fimbriatus* (Ulrich); Copeland, pp. 23-24, pl. 3, fig. 16; pl. 4, fig. 9.

1974 *"Aparchites"* sp. cf. *"Aparchites" fimbriatus* (Ulrich); Copeland, pl. 8, figs. 15-16.

?1974 *Aparchites* sp. Kay *in* Bergstrom, Riva and Kay, p. 1629, (not figured).

1977c *"Aparchites"* sp. cf. *"Aparchites" fimbriatus* (Ulrich); Copeland, pl. 2, fig. 7; pl. 4, fig. 19; pl. 6, fig. 1.

1977 *"Aparchites" fimbriatus* (Ulrich); Copeland *in* Copeland and Bolton, p. 3, pl. 1.1, fig. 21.

1978 *"Aparchites" fimbriatus* (Ulrich); Copeland, pl. 1, fig. 6.

?1982 *"Aparchites"* sp. Warshauer and Berdan, pp. H49-H50, pl. 10, fig. 7.

?1982 *"Aparchites" fimbriatus* (Ulrich); Copeland, pl. 7, fig. 11; pl. 9, fig. 1.

1985 *Brevidorsa fimbriata* (Ulrich); Schallreuter and Siveter, pl. 69, fig. 5.

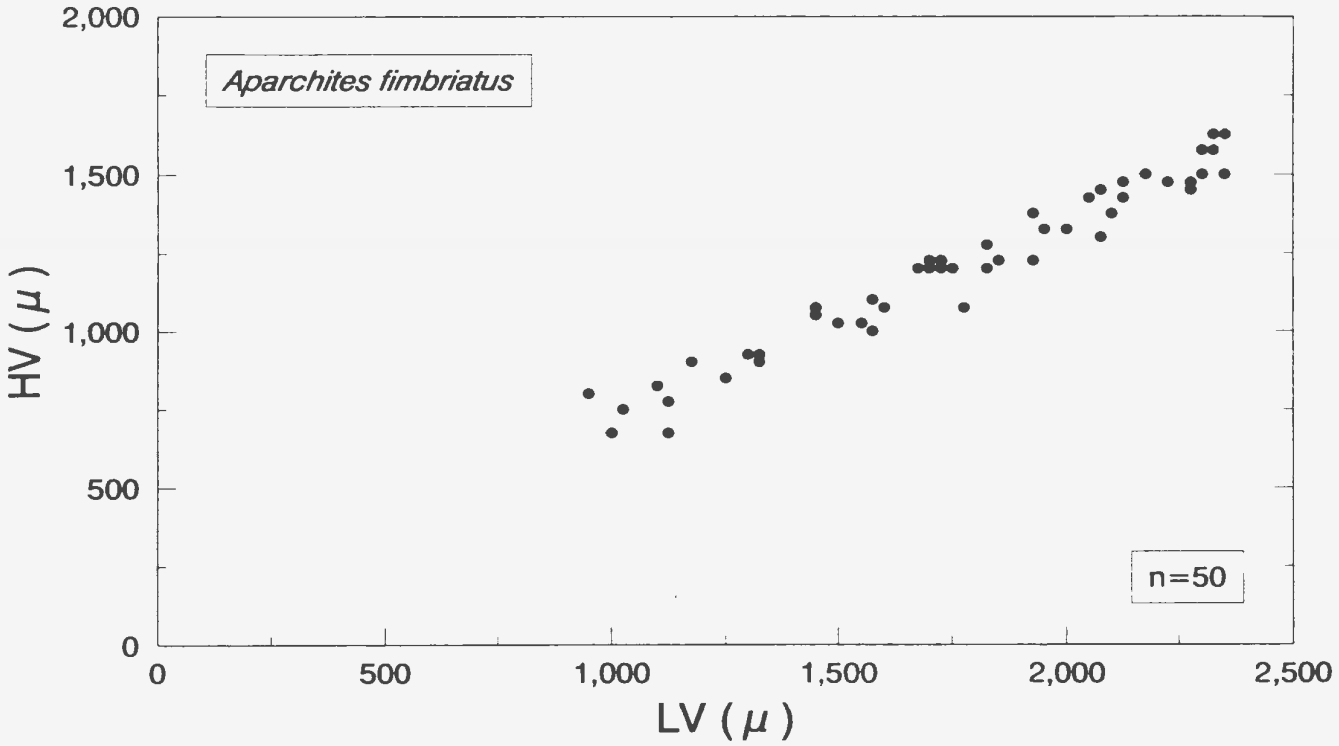
?1985 *Brevidorsa crassispinosa* (Schallreuter); Schallreuter and Siveter, pl. 69, fig. 6.

Holotype.- *Leperditia fimbriata* Ulrich 1892, p. 268, pl. 9, figs. 34-36.

Diagnosis.- See Swain *et al.* (1961, pp. 351-353) and Kraft (1962, pp. 28-29).

Description.- Valves subovate to subelliptical in lateral view. HV at about mid-length, LV at about mid height, WV ventromedianly. Dorsal margin straighter than more evenly rounded free margin. Simple straight, slightly depressed hinge. Valves swollen and unequal, right valve overlaps left valve. Ventral surface flattened and inset. Thickened velate ridge or flange along free margin, ridge ventrally denticulate. Surface smooth to finely granulose. No dimorphism recognised.

Measurements.- The specimens of *Aparchites fimbriatus* exhibit continuous size variation (Text-fig. 17). There are signs of instar development, but more specimens are needed to define these instar patterns.



Text-fig. 17. Size dispersion diagram of *Aparchites fimbriatus* (Ulrich 1892) from samples L-8 and S-6.

Remarks.- Swain *et al.* (1961, p. 351) noted that *Aparchites fimbriatus* is dimorphic, the heteromorphs being more elongate and elliptical than the tecnomorphs. In a later study, Copeland (1974, p. 23) was unable to recognise this supposed dimorphism. Unfortunately, the present collections are too small to confirm or reject either viewpoint. Marginal spinosity or nodosity is highly variable in *Aparchites fimbriatus* and ranges from small separate nodes to closely spaced spines. The taxonomic position of *Aparchites fimbriatus* is uncertain. According to Hessland *in* Moore (1961, p. Q171), it would be better to group *Aparchites fimbriatus* with the oepikellid forms. Copeland (1965, p. 30) concurred with Hessland, and after re-examining the

type species *Aparchites whiteavesi* Jones 1889, noted (Copeland 1970, p. 23) that *"Aparchites" fimbriatus* probably does not belong within *Aparchites*. The species of *Aparchites* described by Carter (1957, pp. 103-108) are instars, possibly of *Aparchites fimbriatus*. A number of the species of *Tvaerenella* illustrated by Sarv (1959, pl. 5) are similar to *Aparchites fimbriatus*.

Material.- Material consists of fifteen carapaces from sample (L-8); some of these carapaces are well preserved and show surface detail, others are flattened internal moulds. The Carter Collection contains at least eighty well-preserved calcified carapaces and valves. Of these, only the eighteen carapaces and valves from sample (S-6) were examined in detail.

Occurrence.- Beach Point Member (L-8), Lourdes Formation, western Newfoundland. Beekmantown, Chazy, Black River and Trenton groups at numerous localities in the Laval, Laurentides, Sorel, Trois-Rivières, Grondines, Portneuf and St. Raymond map-areas, St. Lawrence Lowlands, (see Carter 1957, p. 80 for details). The specimens examined are from the Montréal Formation (S-6), Laval map-area, St. Lawrence Lowlands.

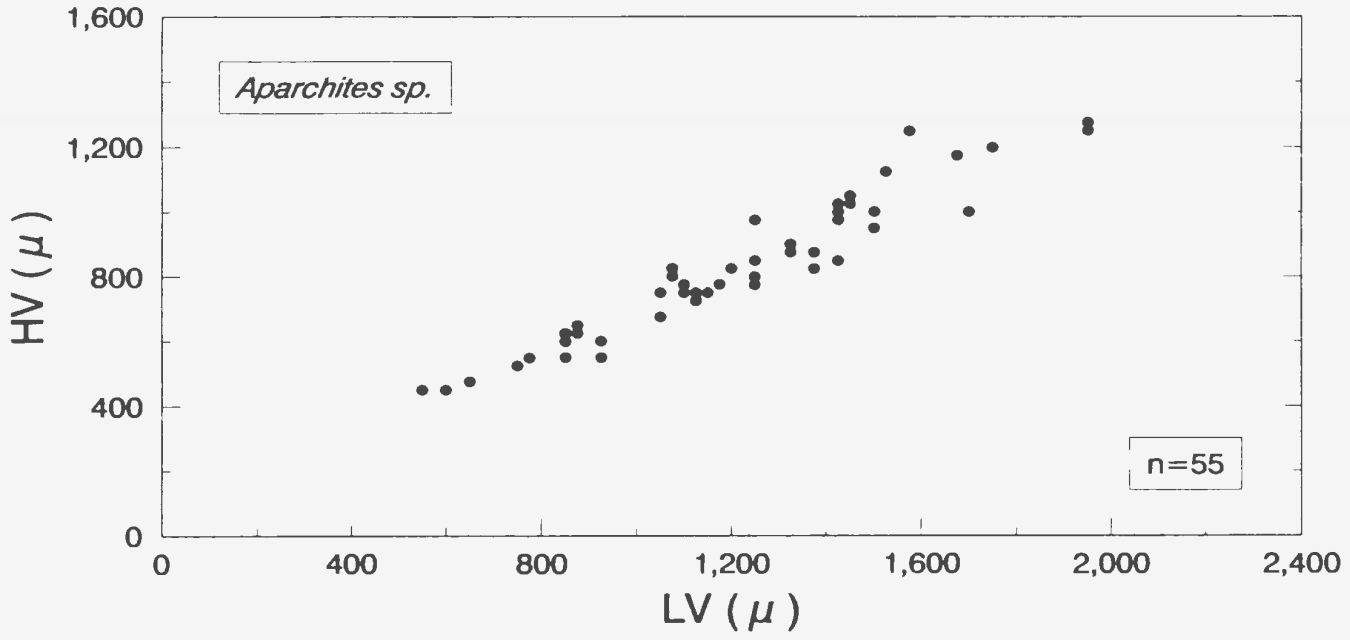
Aparchites sp.

Pl. 13, fig. 7; text-fig. 16b.

Description.- Valves subovate and dorsally truncate. HV at about mid-length, LV at about mid-height, WV ventromedially. Dorsal margin straight to slightly sinuous, free margins evenly rounded. Simple straight, slightly depressed hinge. Anterior cardinal angle about 120°, posterior cardinal angle about 140°. Sub-equivalved, both valves swollen. Ventral surface somewhat flattened. Some valves have a thickened

and finely beaded ridge around the free margins. Surface smooth to finely granulose. No dimorphism recognised.

Measurements.- The specimens of *Aparchites* sp. exhibit continuous size variation (Text-fig. 18). There are signs of instar development, but more specimens are needed to define these instar patterns.



Text-fig. 18. Size dispersion diagram of *Aparchites* sp. from samples T-4 and T-5.

Remarks.- *Aparchites* sp. is similar to *Aparchites fimbriatus* (Ulrich 1892), but is described as a separate species here, because it has a much straighter dorsal margin, is more equivalved and has less pronounced marginal denticulation.

Material.- At least seventy corroded carapaces from washings of weathered material, some are steinkerns, others have their original shells preserved.

Occurrence.- Most common in weathered material (T-4, T-5), from the middle of the Table Point Formation, western Newfoundland.

Genus *Saccelatia* Kay 1940

Type species.- *Aparchites arrectus* Ulrich 1894

Diagnosis.- See Kay (1940, pp. 242-343) and Hessland *in* Moore (1961, pp. Q171-Q172).

Occurrence.- Known from the Middle Ordovician of North America and Europe. (Hessland *in* Moore 1961, pp. Q171-Q172).

Saccelatia arrecta (Ulrich 1894)

Pl. 14, fig. 1; text-fig. 16c.

Synonymy.-

1894	*Aparchites? arrectus* Ulrich, p. 646, pl. 43, figs. 35-36.
?1894	*Aparchites millepunctatus* Ulrich, p. 645, pl. 45, figs. 16-18.
1940	*Saccelatia arrecta* (Ulrich); Kay, p. 243, pl. 29, figs. 12-16.
1944	*Saccelatia arrecta* (Ulrich); Shimer and Shrock, p. 665, pl. 280, figs. 38-40.
1948	*Saccelatia arrecta* (Ulrich); Wright, pl. 2, figs. 17-21, (unpublished).
1956	*Saccelatia arrecta* (Ulrich); Cornell, p. 74, pl. 7, figs. 1-4, (unpublished).
?1957	*Aparchites millepunctatus* Ulrich; Harris, pp. 140-141, pl. 2, figs. 1a-d.
1957	*Saccelatia arrecta* (Ulrich); Swain, pp. 561-562, pl. 62, fig. 6.
?1957	*Saccelatia* sp. Swain, pl. 62, fig. 17.
1961	*Saccelatia arrecta* (Ulrich); Hessland *in* Moore, pp. Q171-Q172, figs. 107.4a-b, 108.1a-c.
?1961	*Saccelatia kellettae* Levinson, pp. 360-361, pl. 1, figs. 1a-d.
1961	*Saccelatia arrecta* (Ulrich); Swain, Cornell and Hansen, p. 356, pl. 47, figs. 4a-e; text-fig. 2d.
?1965	*Saccelatia buckensis* Copeland, p. 32, pl. 5, figs. 1, 4-5, 13-14; pl. 10, fig. 1.
1971	*Saccelatia arrecta* (Ulrich); Copeland *in* Steele and Sinclair, pl. 23, figs. 5-7.

1977 *Saccelatia arrecta* (Uirich); Copeland *in* Copeland and Bolton, pl. 1.1, fig. 14.

Holotype.- *Aparchites arrectus* Ulrich 1894, p. 646, pl. 43, figs. 35-36.

Diagnosis.- See Kay (1940, p. 343).

Description.- Valves subovate and dorsally truncate. Valves amplete; HV at about mid-length, LV just above mid-height and WV below mid-height. Dorsal margin straight, free margins evenly rounded. Cardinal angles distinct and slightly projecting. Anterior cardinal angle about 130°, posterior cardinal angle about 110°. Valves evenly convex, but ventrally swollen. Ventral margin flattened. Contact margin faintly denticulate. Surface finely but densely reticulate.

Measurements.- LV 1125 μ, 900 μ, 875 μ, 775 μ, 750 μ, 675 μ.
HV 725 μ, 525 μ, 575 μ, 550 μ, 525 μ, 400 μ.

Remarks.- Other species of *Saccelatia*, such as *Saccelatia angularis* (Ulrich 1894), *Saccelatia arcuamuralis* Kay 1940, *Saccelatia bullata* Kay 1940 and *Saccelatia cletifera* Kay 1940 differ from *Saccelatia arrecta* in having ridges and/or nodes on their ventral surfaces. More comparative material is needed in order to ascertain whether these contrasting morphologies reflect intraspecific variability, or specific differences. *Saccelatia arrecta* is similar to *Aparchites millepunctatus* (Ulrich 1894), as identified by Harris (1957, pp. 140-141, pl. 2, figs. 1a-d).

Material.- Eleven corroded carapaces; some specimens have their original shell material preserved.

Occurrence.- Beach Point Member, Lourdes Formation (L-8, L-9, L-11), western Newfoundland.

Family SCHMIDTELLIDAE Neckaja 1966

Diagnosis.- See Berdan (1988, p. 287).

Genus *Schmidtella* Ulrich 1892

Type species.- *Schmidtella crassimarginata* Ulrich 1892

Diagnosis.- See Levinson and Moore *in* Moore (1961, p. Q193).

Occurrence.- Known from the Middle Ordovician to Middle Devonian of North America and Europe, (Levinson and Moore *in* Moore 1961, p. Q193).

Schmidtella sublenticularis (Jones 1890)

Pl. 14, fig. 2; text-fig. 16d.

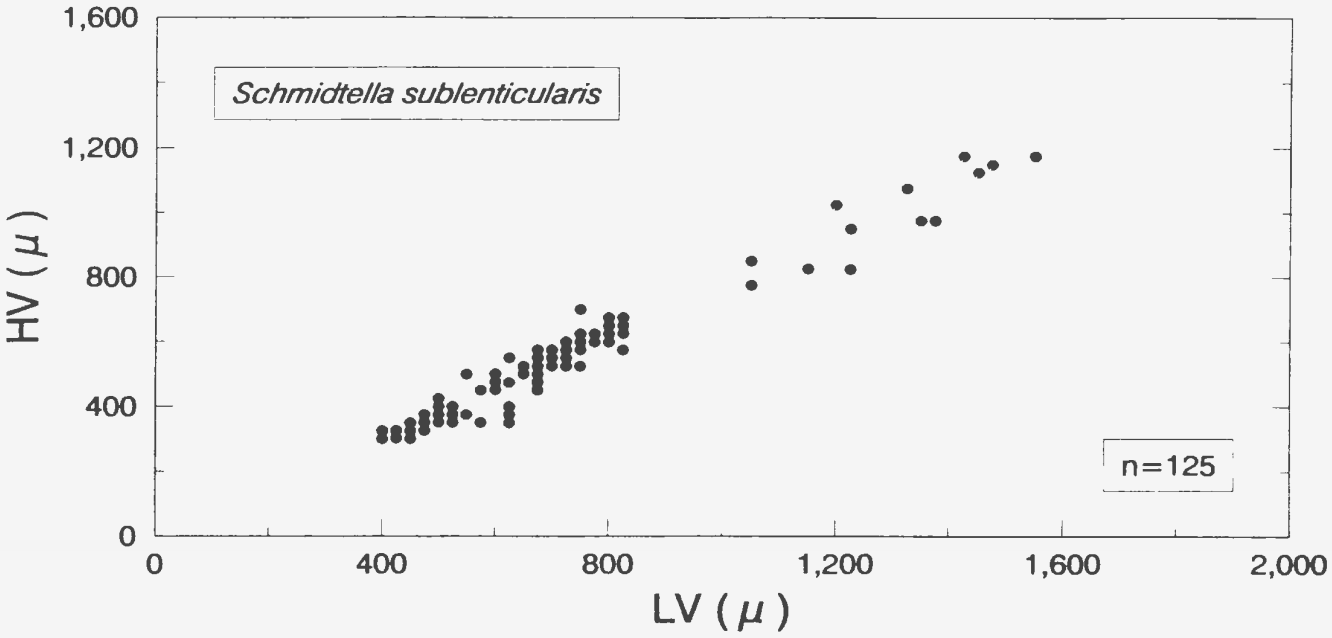
Synonymy.-
1890a *Polycope sublenticularis* Jones, p. 550, pl. 21, figs. 6a-b.
?1928 *Schmidtella sublenticularis* (Jones); Bassler *in* Twenhofel, p. 342, (not figured).
1970 *Schmidtella sublenticularis* (Jones); Copeland, p. 22, pl. 4, fig. 23.
1973 *Schmidtella sublenticularis* (Jones); Copeland, pl. 1, figs. 5-6; pl. 6, figs. 21-22, 26-29.
?1973 *Schmidtella robervali* Copeland, p. 22, pl. 1, figs. 9-10; pl. 2, fig. 18; pl. 3, fig. 23; pl. 5, figs. 1-2.

Holotype.- *Polycope sublenticularis* Jones 1890a, p. 550, pl. 21, figs. 6a-b.

Diagnosis.- See Jones (1890a, p. 550) and Copeland (1970, p. 22).

Description.- Valves subovate, amplete and sometimes umbonate. LV at about mid-height, HV at about mid-length. Dorsal margin slightly convex, free margins evenly rounded. Simple straight hinge sunken between the raised dorsal shoulders of both valves. Equivalved, some valves smooth, others have a faint central depression or more distinctive pit. No dimorphism observed.

Measurements.- The specimens of *Schmidtella sublenticularis* fall into two distinct groups (Text-fig. 19): a group of larger adults and a group of much more common juveniles.



Text-fig. 19. Size dispersion diagram of *Schmidtella sublenticularis* (Jones 1890) from samples A-7 and A-9.

Remarks.- Copeland (1973) recognised taxa with a central pit as a separate species, *Schmidtella robervali*. This author prefers to tentatively include these taxa in *Schmidtella sublenticularis*, because aside from the central pit, the two groups of taxa are morphologically identical. When Ulrich (1892) established the genus *Schmidtella*, he recognised seven new species, namely *Schmidtella affinis*, *Schmidtella brevis*, *Schmidtella crassimarginata*, *Schmidtella incompta*, *Schmidtella incompta* var. *subaequalis*, *Schmidtella subrotunda* and *Schmidtella umbonata*, some, if not most of which are synonymous. Later workers, like Kay (1940), Harris (1957), Swain *et al.* (1961) and Swain (1962) grouped their taxa in Ulrich's species and did not recognise the extent to which ostracodes vary intraspecifically. Until *Schmidtella* is thoroughly revised, including a re-examination and re-illustration of the type material, it is not possible to assess to what extent *Schmidtella sublenticularis* is synonymous with Ulrich's (1892) original taxa.

Material.- Fifty-eight carapaces and about three hundred valves; all the specimens are reasonably well preserved.

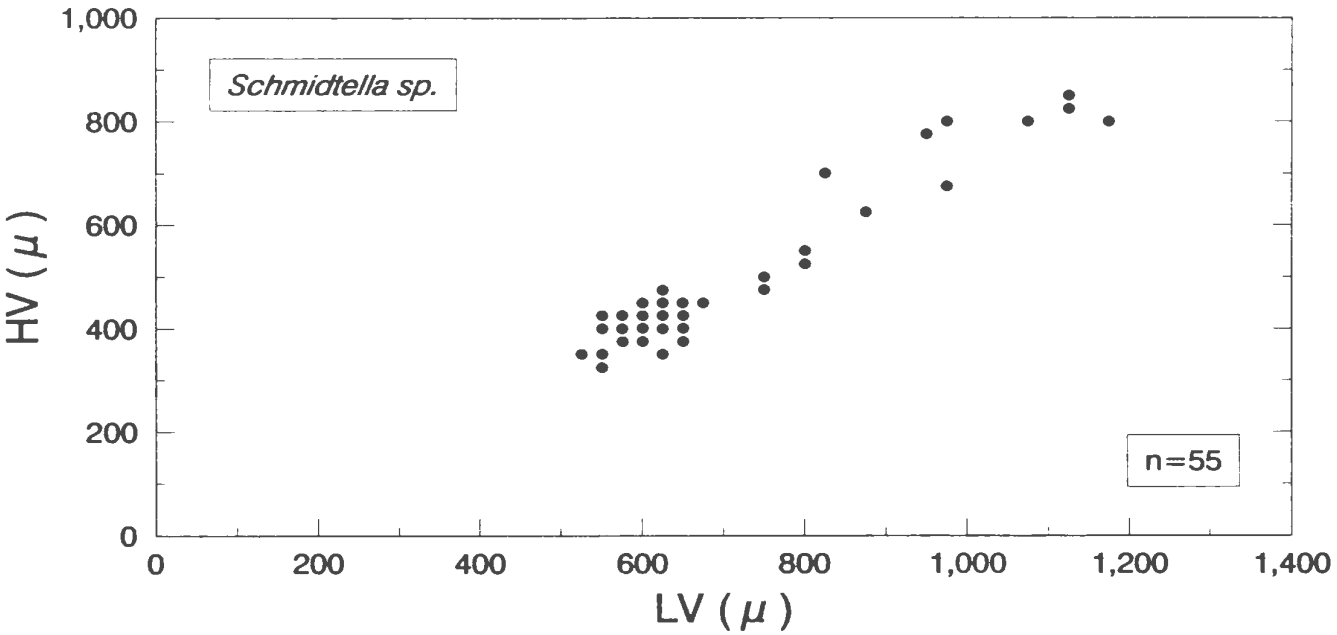
Occurrence.- Vauréal Formation (A-1, A-3, A-8) and Members 1 (A-7, A-9), 2 (A-13), 3 (A-11), 4 (A-14, A-15) and 5 (A-12, A-16), Ellis Bay Formation, Anticosti Island.

Schmidtella sp.

Pl. 14, figs. 3-4; text-figs. 16e-f.

Description.- Valves subovate to subelliptical and sometimes umbonate. Dorsal margin generally straighter than more evenly rounded free margins. HV at about mid-length, LV at about mid-height. Slightly sunken, simple straight hinge. Equivalved, most valves smooth, some very finely granulose. No dimorphism observed.

Measurements.- The specimens of *Schmidtella* sp. exhibit continuous size variation (Text-fig. 20). Instar patterns are not well developed, but juveniles are more common than adults.



Text-fig. 20. Size dispersion diagram of *Schmidtella* sp. from samples L-1, L-4, L-8, L-9, L-10 and L-11.

Remarks.- *Schmidtella* sp. is almost certainly synonymous with *Schmidtella umbonata* Ulrich 1892, as figured by Copeland and Bolton (1977, pl. 1.1, figs. 15, 17) from the Lourdes Formation. Despite this, the present author is not confident in assigning *Schmidtella* sp. to this or any other species of *Schmidtella* for two main reasons. First, the present collections are dominated by poorly preserved juveniles and second (as noted above) the taxonomy of *Schmidtella* is in need of revision.

Material.- Ten carapaces and seventy-nine valves; no original shell material is preserved. All the specimens are corroded and have been entirely recrystallised or replaced.

Occurrence.- Black Duck (L-2, L-4) and Beach Point (L-8, L-9, L-10, L-11) members, Lourdes Formation, western Newfoundland.

Suborder KLOEDENELLOCOPINA Scott 1961

Diagnosis.- See Scott *in* Moore (1961, p. Q180).

Remarks.- The Kloedenellocopina is not a natural grouping and includes both dimorphic and non-dimorphic forms. The most conspicuous feature common to all kloedenellocopines is that they have strongly overlapping valves. See Scott *in* Moore (1961, pp. Q85-Q86) for further discussion of the Kloedenellocopina.

Superfamily LEPERDITELLACEA Ulrich and Bassler 1906

(*nom. transl.* Jaanusson 1957)

Diagnosis.- See Jaanusson (1957, pp. 412-413) and Scott *in* Moore (1961, pp. Q187-Q188).

Remarks.- The stratigraphic ranges of the various leperditellacean genera are shown graphically in Moore (1961, p. Q189).

Family LEPERDITELLIDAE Ulrich and Bassler 1906

Diagnosis.- See Bassler and Kellett (1934, p. 14), Henningsmoen (1953a. p. 250), Jaanusson (1957, pp. 414-415) and Levinson and Moore *in* Moore (1961, p. Q188).

Remarks.- The leperditellids are characteristically straight hinged and unisulcate, they lack any marginal or velar structures.

Genus *Leperditella* Ulrich 1894

Type species.- *Leperditella rex* (Coryell and Schenck 1941)

Diagnosis.- See Ulrich (1894, pp. 636-637), Ulrich and Bassler (1923a, p. 297), Harris (1957, pp. 147-148), Levinson and Moore *in* Moore (1961, p. Q188) and Kraft (1962, p. 19).

Remarks.- The taxonomy of *Leperditella* is complex and in need of a thorough revision. *Leperditella* has been used as a "sack" genus and contains some taxa which are unrelated. Confusion over the name of the type species was largely resolved when Coryell and Schenck (1941) designated *Leperditella rex* as a lectotype.

Occurrence.- Known from the Middle to Upper Ordovician of North America and Europe, (Levinson and Moore *in* Moore 1961, p. Q188).

Leperditella rex (Coryell and Schenck 1941)

(*nom. subst. pro Leperditia inflata* Ulrich 1892)

Pl. 14, figs. 5-6; text-figs. 16g-h.

Synonymy.-

non 1839 *Cypris inflata* Murchison, p. 84, figs. A1-3.
1892 *Leperditia inflata* Ulrich, p. 265, pl. 9, figs. 12-15.
1894 *Leperditella inflata* (Ulrich); Ulrich, p. 636, text-figs. 46a-d.

?1894 *Leperditella sulcata* Ulrich; Ulrich, p. 636, text-fig. 46j.

1923a *Leperditella inflata* (Ulrich); Ulrich and Bassler, fig. 14, nos. 1-2.

1934 *Leperditella inflata* (Ulrich); Bassler and Kellett, p. 14, fig. 5, nos. 1-2 and p. 374.

1941 *Leperditia rex* Coryell and Schenck, p. 176.

1941 *Leperditella rex* (Coryell and Schenck); Coryell and Schenck, p. 177, text-fig. 1.

1944 *Leperditella rex* (Coryell and Schenck); Shimer and Shrock, p. 664, pl. 280, figs. 1-4.

1948 *Leperditella inflata* (Ulrich); Wright, pl. 1, figs. 25-26, (unpublished).

1952 *Leperditella rex* (Coryell and Schenck); Moore, Lalicker and Fischer, p. 526, fig. 14.3, no. 10.

1957 *Leperditella rex* (Coryell and Schenck); Carter, pp. 82-84, pl. 4, figs. 1a-d, (unpublished).

?1957 *Leperditella rex* var. *punctata* (Coryell and Schenck); Carter, pp. 84-85, pl. 3, figs. 5a-d, (unpublished).

?1957 *Leperditella? jonesinoides* Harris, pp. 153-154, pl. 3, figs. 6a-b.

1957 *Leperditella rex* (Coryell and Schenck); Harris, pp. 156-157, pl. 3, fig. 2.

1957 *Leperditella rex* subsp. *minima* (Coryell and Schenck); Harris, p. 157, pl. 3, figs. 3a-b.

?1957 *Leperditella tumida* (Ulrich); Harris, pp. 158-159, pl. 3, figs. 10a-b.

1957 *Leperditella rex* (Coryell and Schenck); Swain, p. 562, pl. 62, figs. 3a-d.

?1957 *Leperditella aequilatera* (Ulrich); Swain, pp. 562-563, pl. 62, fig. 4.

?1957 *Leperditella mundula* (Ulrich); Swain, p. 563, pl. 62, fig. 5.

?1957 *Leperditella sulcata* (Ulrich); Swain, p. 563, pl. 62, fig. 7.

1961 *Leperditella rex* (Coryell and Schenck); Levinson and Moore *in* Moore, p. Q188, figs. 132.1a-b.

?1965 *Primitiella paucisulcata* Burr and Swain, pp. 21-22, pl. 2, figs. 3, 5-7, 9-11, 13, 20.

1965 *Leperditella rex* (Coryell and Schenck); Copeland, p. 35, pl. 8, figs. 11-13.

?1971 *Leperditella* sp. cf. *Leperditella tumida* (Ulrich); Copeland *in* Steele and Sinclair, pl. 23, fig. 25.

?1987 *Hallatia?* sp. Berdan *in* Ross and James, p. 95, (not figured).

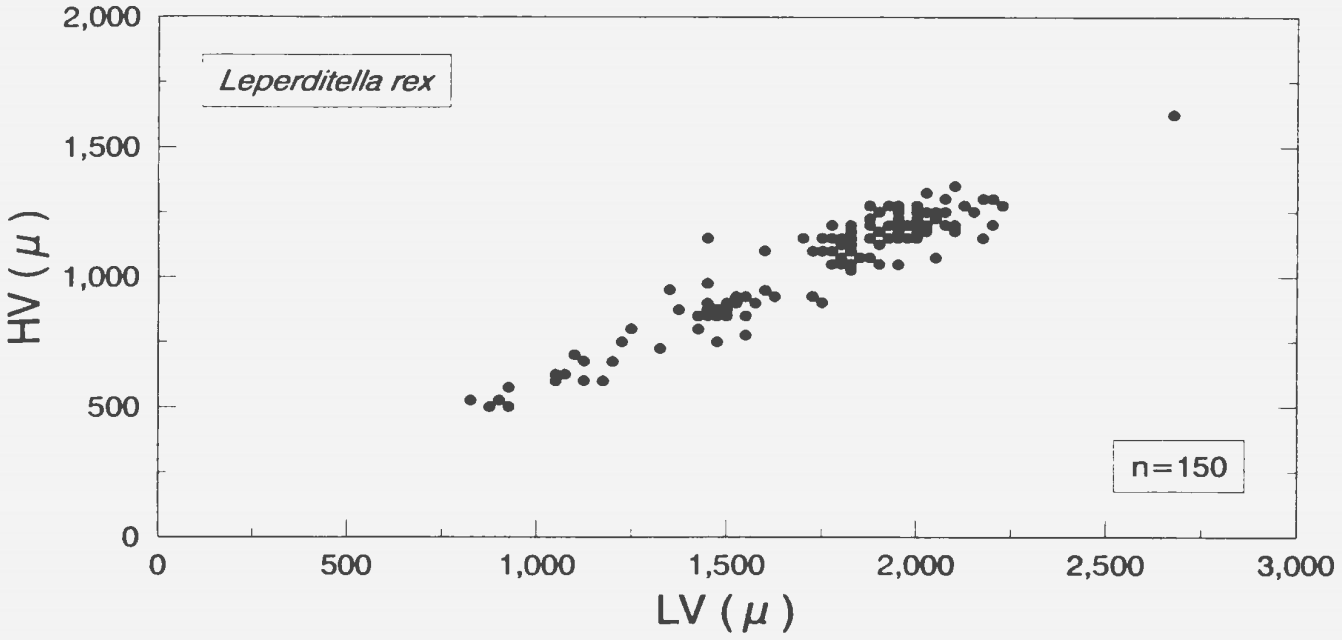
?1987 *Leperditella?* sp. Berdan *in* Ross and James, p. 95, (not figured).

Holotype.- *Leperditia inflata* Ulrich 1892 was originally designated as the holotype, but since this name is a primary homonym of *Leperditia inflata* (Murchison 1839), it was deemed invalid by Coryell and Schenck (1941) who renamed the taxon *Leperditella rex* and designated a lectotype from Ulrich's (1892) syntypes. See Coryell and Schenck (1941, pp. 176-177) for further discussion of the type material of *Leperditia inflata* and *Leperditella rex*.

Diagnosis.- See Ulrich (1892, p. 265) and Coryell and Schenck (1941, pp. 176-177).

Description.- Valves subovate to subelliptical in lateral view. Valves postplete; HV posterior of mid-length, LV at about mid-height, WV posteromedianly. Dorsal margin sinuous, anterior third straighter than upwardly arched posterior two thirds. Ventral margin slightly convex; anterior and posterior margins more evenly rounded. Simple hinge forms straight anterior portion of dorsal margin, but is depressed below upwardly arched valves, posteriorly. Valves swollen, particularly posteriorly. Slightly inequivalved; left valve larger than right valve. Shallow, median to mid-dorsal sulcus. Surface smooth to irregularly granulose.

Measurements.- The size dispersion diagram for *Leperditella rex* shows well developed instar patterns (Text-fig. 21).



Text-fig. 21. Size dispersion diagram of *Leperditella rex* (Coryell and Schenck 1941) from samples T-4 and T-5.

Remarks.- Coryell and Schenck (1941) renamed *Leperditella inflata* (Ulrich 1892), *Leperditella rex*, because they considered *Leperditia inflata* Ulrich 1892 an invalid junior homonym of a different nominal taxon, *Leperditia inflata* (Murchison 1839). To prevent further confusion all subsequent authors have followed Coryell and Schenck's (1941) *nomen novum, Leperditella rex*. Further revision of *Leperditella rex* awaits re-examination and re-description of Ulrich's (1892 and 1894) type material. Several of the species of *Primitiella* described by Hessland (1949) are similar to *Leperditella rex*.

Material.- At least one hundred and fifty corroded carapaces from washings of weathered material (T-4, T-5); some are steinkerns, others have their original shells preserved. In addition, about fifteen vibra-tool prepared valves from the more indurate limestones of samples T-3 and T-7.

Occurrence.- *Leperditella rex* occurs throughout the Table Head Group, western Newfoundland, but is most common in the lower and middle Table Point Formation, where it is common in weathered material (T-4, T-5) and on bedding planes in association with leperditiids (T-3, T-7).

Leperditella **sp. 1**

Pl. 14, fig. 7; text-fig. 16i.

Synonymy.- **1957** *Leperditella centrinota* Carter, pp. 69-71, pl. 2, figs. 4a-d, (unpublished).

Description.- Valves subovate and dorsally truncate. HV at about mid-length, LV at about mid-height. Dorsal margin almost straight, free margins evenly rounded. Anterior and posterior cardinal angles about 120°. Narrow crescentic rim around free margins. Distinctive, subcircular muscle scar at mid-valve. Surface smooth.

Measurements.- LV 2525 μ, 2200 μ.
HV 1825 μ, 1650 μ.

Remarks.- Lack of material precludes more certain identification of *Leperditella* sp. 1. The muscle scar in *Leperditella* sp. 1 is reminiscent of the sulcal depression in the tvaerenellids.

Material.- Two valves, both have their original shell material preserved, (Carter Collection, Redpath Museum).

Occurrence.- Trenton Group (S-11, S-21), Sorel and Portneuf map-areas, St. Lawrence Lowlands.

Leperditella **sp. 2**

Pl. 14, fig. 8.

Synonymy.- ?1957 *Leperditella elliptica* Carter, pp. 71-73, pl. 2, figs. 5a-e, (unpublished).

Description.- Valves subovate and unequal; left valve overlaps right valve. HV at about mid-length, LV at about mid-height. Left valve evenly rounded; right valve dorsally truncate, but otherwise evenly rounded. Narrow crescentic rim extends around free margins of both valves. Obscure central muscle scar. Surface smooth to faintly punctate.

Measurements.- LV 2050 μ, 1525 μ, 1475 μ, 1200 μ, 1050 μ.
HV 1375 μ, 1025 μ, 1150 μ, 950 μ, 775 μ.

Remarks.- *Leperditella* sp. 2 is similar to *Leperditella canalis* Ulrich 1894 and the tecnomorphs of *Oepikella labrosa* Copeland 1965.

Material.- Twenty-five carapaces and valves; all the specimens have their original shell material preserved.

Occurrence.- Deschambault Formation (S-4, S-5), Laurentides and Trois-Rivières map-areas, St. Lawrence Lowlands.

Genus *Ectoprimitia* Bouček 1936

Type species.- *Primitia corrugata* Krause 1892

Diagnosis.- See Levinson and Moore *in* Moore (1961, p. Q191).

Remarks.- Hessland (1949, p. 224) and Kraft (1962, pp. 72-73) discuss the differences between the genera *Ectoprimitia* and *Primitiella* Ulrich 1894.

Occurrence.- Known from the Ordovician of Europe and North America, (Levinson and Moore *in* Moore 1961, p. Q191).

Ectoprimitia? sp.

Pl. 15, fig. 1; text-fig. 16j.

Description.- Valves subquadrate. HV anterior of mid-length, LV at about mid-height. Dorsal margin straight, ventral nargin subparallel but slightly concave.

Anterior and posterior margins evenly rounded. Cardinal angles abrupt; anterior cardinal angle about 130°, posterior cardinal angle about 110°. Distinctive, mid to anterodorsal, crescent shaped sulcus divides valve into a swollen L1 and a more flattened L2. Some of the valves have a slight posteroventral alate projection. Shell surface densely reticulate.

Measurements.- LV 875 μ, 850 μ, 800 μ.
HV 475 μ, 525 μ, 450 μ.

Remarks.- Assignment of this taxon to *Ectoprimitia* is only tentative, because a lack of material precludes recognition of either dimorphism or the nature of ontogenetic development. Other species of *Ectoprimitia* differ from *Ectoprimitia?* sp. in having a smoother or more granulose ornament. *Ectoprimitia?* sp. is reminiscent of the species of *Parabolbina* Swartz 1936 that were described by Kay (1940, pp. 255-256).

Material.- Three somewhat flattened carapaces and one valve; some original shell material is preserved in the specimens.

Occurrence.- Beach Point Member (L-9), Lourdes Formation, western Newfoundland.

Genus *Hallatia* Kay 1934

Type species.- *Hallatia particylindrica* Kay 1934

Diagnosis.- See Kay (1934, p. 335) and Moore and Scott *in* Moore (1961, p. Q191).

Occurrence.- Known from the Middle to Upper Ordovician of central and eastern North America, (Moore and Scott *in* Moore 1961, p. Q191).

Hallatia particylindrica Kay 1934

Pl. 15, fig. 2; text-fig. 16k.

Synonymy.- ?1934 *Hallatia healeyensis* Kay, p. 335, pl. 45, figs. 5-6.

1934 *Hallatia particylindrica* Kay, p. 336, pl. 45, figs. 3-4.
1940 *Hallatia convexa* Kay, p. 253, pl. 31, figs. 21-23.
1940 *Hallatia particylindrica* Kay; Kay, p. 253, pl. 31, figs. 24-25.
1948 *Hallatia particylindrica* Kay; Wright, pl. 10, figs. 25-26, (unpublished).
1956 *Hallatia particylindrica* Kay; Cornell, p. 28, pl. 8, fig. 27, (unpublished).
1957 *Hallatia particylindrica* Kay; Carter, pp. 170-172, pl. 9, figs. 2a-c, (unpublished).
?1965 *Hallatia* sp. cf. *Hallatia particylindrica* Kay; Copeland, p. 43, pl. 10, fig. 13.
?1971 *Hallatia particylindrica* Kay; Copeland *in* Steele and Sinclair, pl. 23, fig. 18.

Holotype.- Kay 1940, p. 336, pl. 45, figs. 3-4.

Diagnosis.- After Kay (1934, p. 336). *Hallatia*, in which the lateral surfaces of the valves are steeply raised above the margins. Posterior margin extended into a histial flange. Sharply defined crescentic sulcus medianly. Surface of valve smooth.

Description.- Valves subovate and dorsally truncate. HV at about mid-length, LV just dorsal of mid-height. Dorsal margin straight, ventral margin convex; posterior margin more evenly rounded than anterior margin. Anterior cardinal angle about 130°, posterior cardinal angle about 110°. Lateral surface convex parallel to length and raised above free margins. Sunken crescentic area forms the postero-lateral surface. Distinct, median, comma-shaped sulcus divides valves into two broad, indistinct lobes. Surface of valve smooth to granulose.

Measurements.- LV 1125 μ, 1100 μ, 975 μ.
HV 700 μ, 675 μ, 600 μ.

Material.- Four valves, the specimens are internal moulds, (Carter Collection, Redpath Museum).

Occurrence.- Deschambault Formation (S-18), Grondines map-area, St. Lawrence Lowlands.

Hallatia canadensis (Bassler 1928)

Pl. 15, figs. 3-4; text-fig. 16l.

Synonymy.- ?1928 *Primitiella canadensis* Bassler *in* Twenhofel, p. 345, (not figured).

1970 *Eokloedenella canadensis* (Bassler); Copeland, pp. 20-21, pl. 4, figs. 13-14; pl. 5, fig. 1.

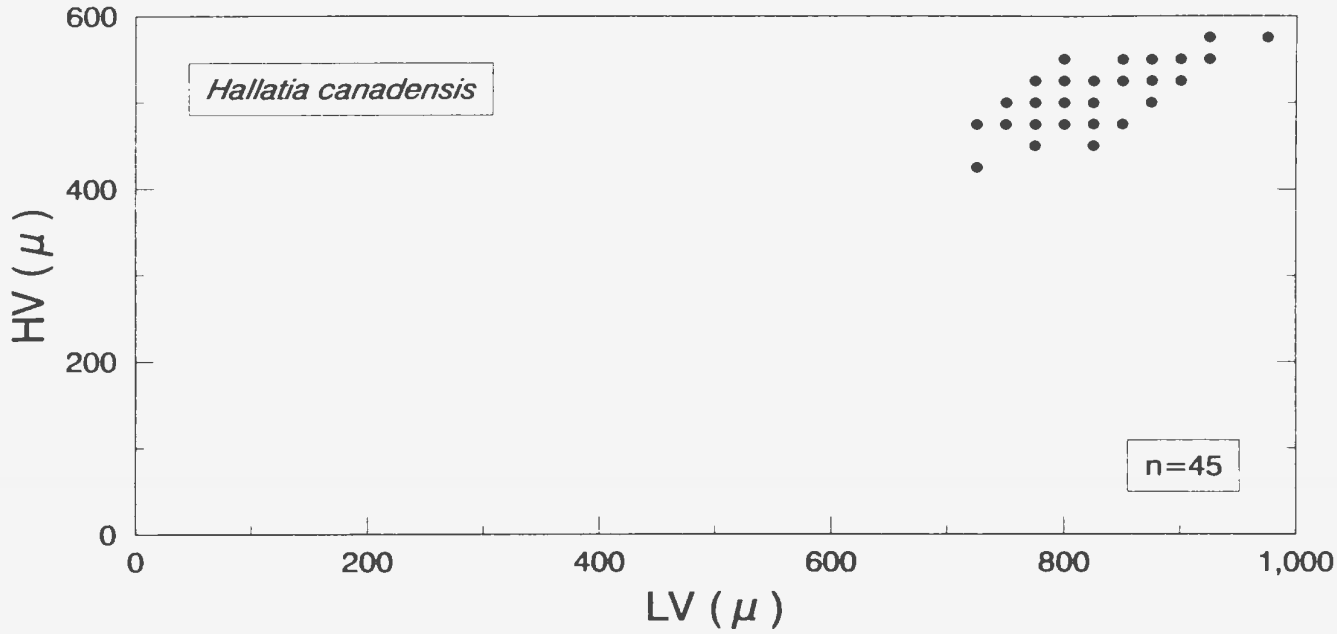
1973 *Eokloedenella canadensis* (Bassler); Copeland, pl. 3, figs. 19-21; pl. 6, figs. 10-13.

Holotype.- *Primitiella canadensis* Bassler *in* Twenhofel 1928, p. 345

Diagnosis.- See Bassler *in* Twenhofel (1928, p.345).

Description.- Valves subquadrate and slightly postplete. HV posterior of mid-length, LV just dorsal of mid-height, WV posteromedianly. Dorsal margin straight, ventral margin convex. Hinge sunken; anterior cardinal angle about 130°, posterior cardinal angle about 100°. Lateral surface convex parallel to length and distinctly raised above narrow marginal surface. Anteroventrally and ventrally, the lateral and marginal surfaces are separated by a groove; the posterior margin is extended into a histial flange. Distinct, median, reverse comma-shaped sulcus divides valves into two ventrally joined flat lobes. Surface of valve smooth to granulose. No sexual dimorphism observed.

Measurements.- All the specimens of *Hallatia canadensis* are roughly the same size (Text-fig. 22). No instar patterns can be recognised and the assemblage is probably size-sorted.



Text-fig. 22. Size dispersion diagram of *Hallatia canadensis* (Bassler 1928) from samples A-12 and A-16.

Remarks.- *Hallatia canadensis* is similar to *Hallatia particylindrica*, but is kept separate here because of differences in overall morphology and sulcation.

The median sulcus in *Hallatia canadensis* is similar to that in *Foramenella phippsi*.

Material.- Forty-six calcified valves; all the specimens are well preserved and show surface detail.

Occurrence.- Member 5 (A-12, A-16), Ellis Bay Formation, Anticosti Island.

Family UNCERTAIN

Genus *Eocytherella* Bonnema 1933

Type species.- None designated.

Diagnosis.- See Howe *in* Moore (1961, p. Q413).

Occurrence.- Known from the Middle to Upper Ordovician of Europe, (Vannier *et al.* 1989).

Eocytherella? **sp.**

Pl. 15, fig. 5; text-fig. 16m.

Description.- Valves elongate and subquadrate in outline. HV anterior of mid-length, LV at about mid-height. Dorsal and ventral margins straight and subparallel. Anterior margin evenly rounded, posterior margin more narrowly rounded. Cardinal angles abrupt; anterior cardinal angle about 140°, posterior cardinal angle about 110°. Lateral surface convex parallel to length. Flattened border around free margins. Posteroventral alate projection. Shell surface densely reticulate.

Measurements.- LV 775 μ, 650 μ.
HV 350 μ, 300 μ.

Remarks.- *Eocytherella?* sp. is morphologically, but not ornamentally similar to *Eocytherella troedssoni* Bonnema 1931 as figured by Vannier *et al.* (1989, pl. 26, fig. 2). Until more material is available, it is not possible to tell whether *Eocytherella?* sp. is a new species, or a juvenile of an existing species.

Material.- Three valves; specimens have some original shell material preserved.

Occurrence.- Beach Point Member (L-9, L-10), Lourdes Formation, western Newfoundland.

Suborder ERIDOSTRACA Adamczak 1961

Diagnosis.- See Adamczak (1961, p. 70).

Remarks.- The lower Paleozoic eridostracans are unique amongst ostracodes, because they show moult retention. There is no consensus on either the taxonomic affiliation or subdivision of the Suborder Eridostraca. See Adamczak (1961), Schallreuter (1968) and Jones (1987) for further discussion of the Eridostraca.

Family ERIDOCONCHIDAE Henningsmoen 1953

(*nom. transl.* Krandijevsky 1958)

Diagnosis.- See Henningsmoen (1953a, p. 266), Adamczak (1961, p. 72) and Jones (1987, p. 102).

Remarks.- Ulrich and Bassler (1923a) were the first to describe moult retaining ostracodes, assigning them to the genus *Eridoconcha*. Since then, a number of other moult retaining genera like *Cryptophyllus* Levinson 1951, *Aberroconcha* Adamczak 1961, *Eridoconchinella* Krandijevsky 1963, *Americoncha* Schallreuter 1968 and *Pygoconcha* Schallreuter 1968 have been established. These genera are justified on the basis of variation in unstable characteristics like size, sculpture and the number of retained moults. As a consequence of this oversplitting, interrelationships between a number of closely allied taxa are complex and in need of revision.

Genus *Eridoconcha* Ulrich and Bassler 1923

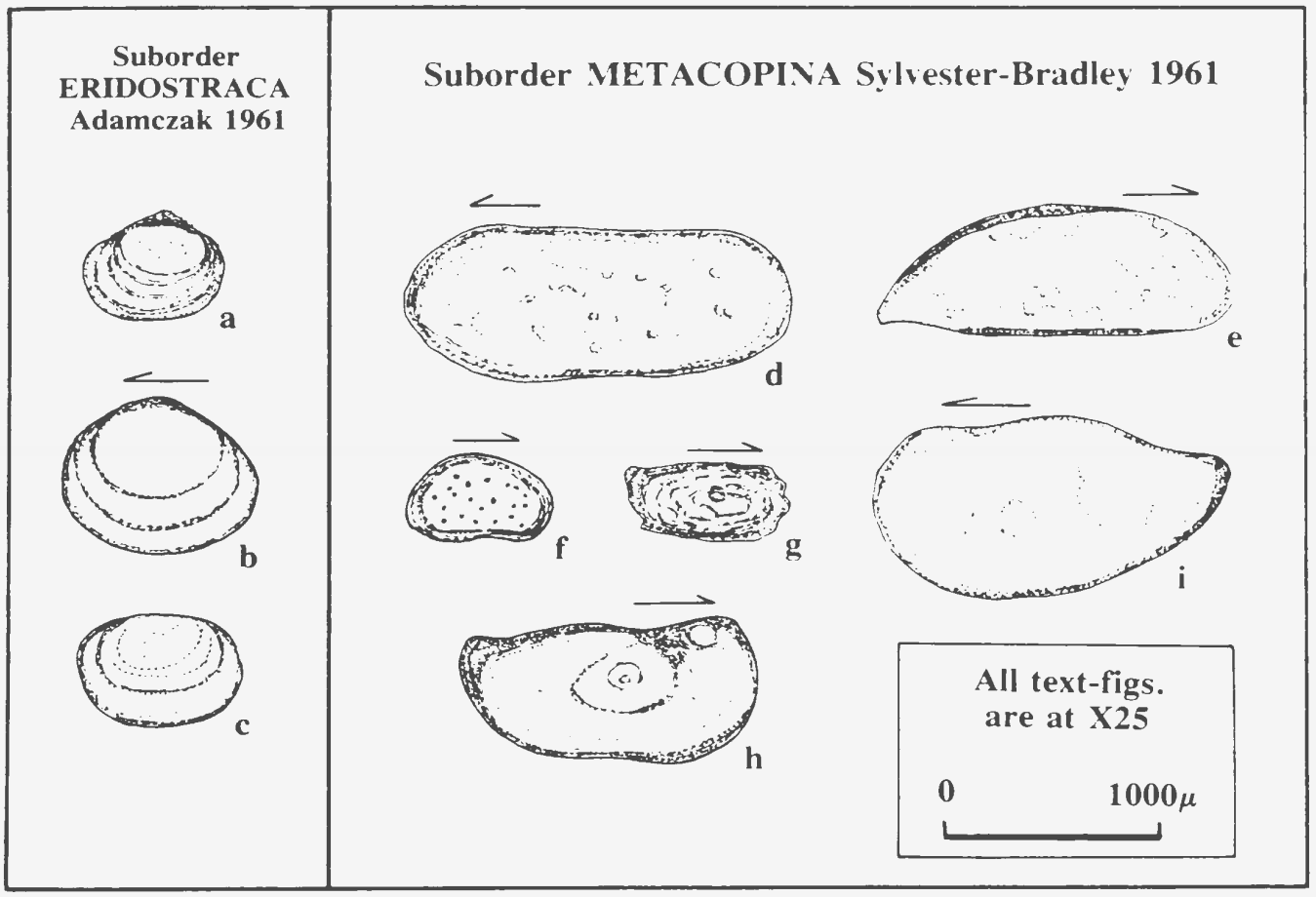
Type species.- *Eridoconcha rugosa* Ulrich and Bassler 1923a

Diagnosis.- See Ulrich and Bassler (1923a, p. 297), Levinson (1951, pp. 556-557), Levinson and Moore *in* Moore (1961, p. Q191) and Jones (1987, p. 103).

Remarks.- A more rigorous generic diagnosis awaits re-description of the poorly known type species *Eridoconcha rugosa*. The relationship between sulcate and non-sulcate species of *Eridoconcha* is not well known. Levinson (1951), Jones (1987, pp. 103-104) and Warshauer and Berdan (1982, pp. H66-H67) discuss *Eridoconcha* in more detail. Differences between *Cryptophyllus* and *Eridoconcha* are discussed under the generic description of *Cryptophyllus*.

Occurrence.- Known from the Middle and Upper Ordovician of North America, (Levinson and Moore *in* Moore 1961, p. Q191).

Text-fig. 23



a. *Eridoconcha rugosa* Ulrich and Bassler 1923
Lourdes Formation, western Newfoundland, (L-9).

b. *Cryptophyllus oboloides* (Ulrich and Bassler 1923)
Ellis Bay Formation, Anticosti Island, (A-15).

c. *Cryptophyllus* sp. aff. *C. oboloides* (Ulrich and Bassler 1923)
Deschambault Formation, St. Lawrence Lowlands, (S-4).

d. *Phelobythocypris cylindrica* (Hall 1871)
Ellis Bay Formation, Anticosti Island, sample A-16.

e. *Krausella arcuata* Ulrich 1894
Leray Formation, St. Lawrence Lowlands, (S-20).

f. *Tubulibairdia jolieti* Copeland 1973
Ellis Bay Formation, Anticosti Island, (A-15).

g. *Eograpiodactylus hyatti* Copeland 1973
Ellis Bay Formation, Anticosti Island, (A-15).

h. *Balticella deckeri* (Harris 1931)
Lourdes Formation, western Newfoundland, (L-8).

i. *Steusloffina ulrichi* Teichert 1937
Deschambault Formation, St. Lawrence Lowlands, (S-18).

Eridoconcha rugosa Ulrich and Bassler 1923

Pl. 15, figs. 7-8; text-fig. 23a.

Synonymy.- 1923a *Eridoconcha rugosa* Ulrich and Bassler, p. 297, fig. 14, no. 9.
1931 *Eridoconcha magnus* Harris, p. 91, pl. 5, figs. 3a-b.
1931 *Eridoconcha simpsoni* Harris, p. 90, pl. 11, figs. 1a-d.
1934 *Eridoconcha rugosa* Ulrich and Bassler; Bassler and Kellett, p. 16, fig. 5, no. 9.
1948 *Eridoconcha rugosa* Ulrich and Bassler; Wright, pl. 1, fig. 33, (unpublished).
?1951 *Cryptophyllus simpsoni* (Harris); Levinson, pp. 557-558 (not figured).
1957 *Cryptophyllus magnum* (Harris); Harris, pp. 181-182, pl. 5, figs. 10a-b.
1957 *Cryptophyllus simpsoni* (Harris); Harris, pp. 183-184, pl. 5, figs. 12, 13a-b, 14a-b, 15a-b.
?1962 *Cryptophyllus sulcatus* Levinson; Guber, pp. 93-94, pl. 3, figs. 6-7, (unpublished).
1974 *Cryptophyllus magnus* (Harris); Copeland, p. 28, pl. 9, figs. 13-16.
?1974a *Cryptophyllus halyei* Copeland, p. 47, pl. 9, fig. 15.
1977 *Cryptophyllus* sp. Copeland *in* Copeland and Bolton, p. 3, pl. 1.1, fig. 16.
?1978a *Cryptophyllus?* sp. Siveter, p. 47, pl. 1, figs. 1-2.
1978 *Cryptophyllus magnus* (Harris); Copeland, pl. 1, fig. 7.
1985 *Cryptophyllus magnus* (Harris); Schallreuter and Siveter, pl. 69, fig. 1.
?1987 *Eridoconcha plerilamella* Jones, pp. 103-104, pl. 30, figs. 11-19.
?1990 *Eridoconcha simpsoni* Harris; Williams and Jones, pp. 13-18, pls. 17.14, 17.16.

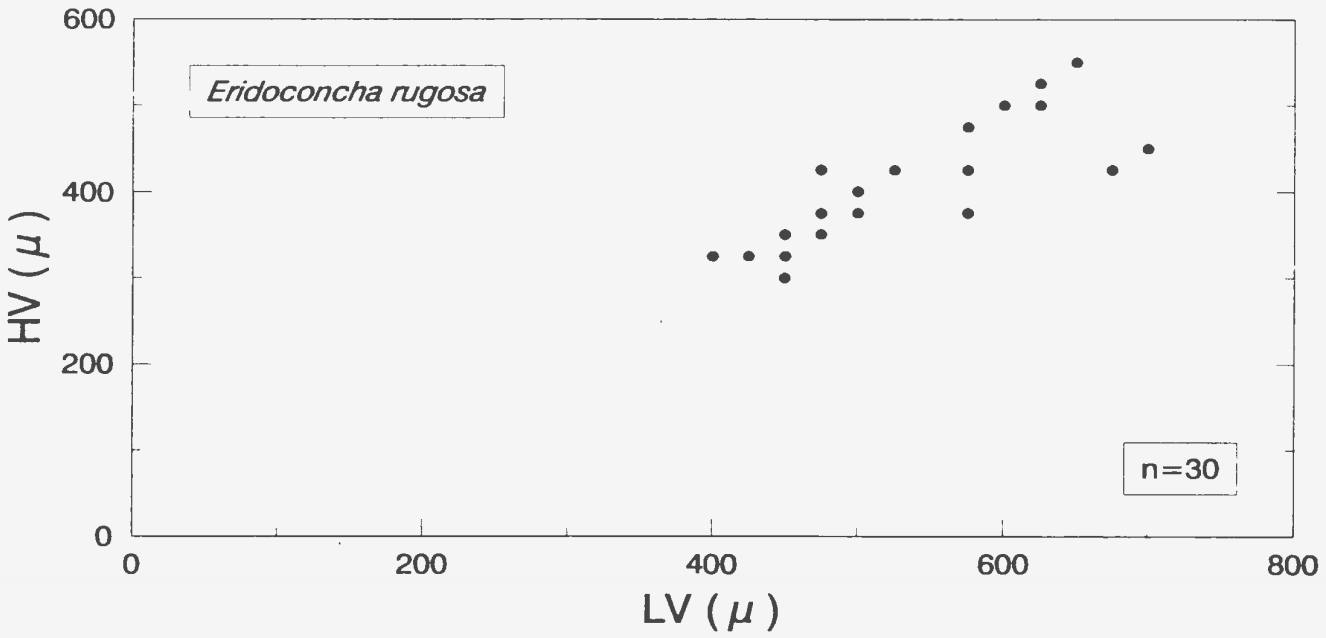
Holotype.- *Eridoconcha rugosa* Ulrich and Bassler 1923a, p. 297, fig. 14, no. 9.

Diagnosis.- See Ulrich and Bassler (1923a, p. 297).

Description.- Valves subovate to subtriangular, and dorsally umbonate. Anterior and posterior margins evenly curved and at about 90° to each other. Ventral margin more

gently curved. HV at about mid-length, LV just below mid-height. Short, straight hinge, sunken between umbones. No sulcation observed. Convex lateral surface with up to ten ridge-like lamellae. Furrows between successive lamellae somewhat U-shaped. Surface smooth.

Measurements.- The specimens of *Eridoconcha rugosa* exhibit continuous size variation (Text-fig. 24). *Eridoconcha rugosa* retains its moults and as a consequence has no instars.



Text-fig. 24. Size dispersion diagram of *Eridoconcha rugosa* Ulrich and Bassler 1923 from samples L-1, L-4, L-8, L-10 and L-11.

Remarks.- A number of previously described species of *Eridoconcha* are included in synonymy here, because apart from minor variations in unstable characteristics like size and the number and nature of retained moults, they are morphologically similar.

Material.- Thirty-six valves, the shell material is entirely recrystallised or replaced. Since most of the valves have at least eight retained moults, they are presumed to be adults.

Occurrence.- Black Duck (L-2, L-4) and Beach Point (L-8, L-9, L-10) members, Lourdes Formation, western Newfoundland.

Genus *Cryptophyllus* Levinson 1951

Type species.- *Eridoconcha oboloides* Ulrich and Bassler 1923a

Diagnosis.- See Levinson and Moore *in* Moore (1961, pp. Q189-Q191).

Remarks.- *Cryptophyllus* differs from *Eridoconcha* in having V-shaped rather than U-shaped inter-lamella furrows, fewer retained moults, a less ridge-like adventral sculpture and a smaller, less well developed sulcus. Schallreuter (1977) discusses the lamella structure and growth mechanisms of *Cryptophyllus*.

Occurrence.- Known from the Middle Ordovician to Upper Jurassic of Europe and North America, (Levinson and Moore *in* Moore 1961, pp. Q189-Q191).

Cryptophyllus oboloides (Ulrich and Bassler 1923)

Pl. 15, fig. 9; text-fig. 23b.

Synonymy.-

1923a *Eridoconcha oboloides* Ulrich and Bassler, p. 297, fig. 14, nos. 6-8.

1934 *Eridoconcha oboloides* Ulrich and Bassler; Bassler and Kellett, p. 16, fig. 5, nos. 6-8.

1940 *Eridoconcha oboloides* Ulrich and Bassler; Kay, pp. 247-248, pl. 29, figs. 34-35.

1948 *Eridoconcha oboloides* Ulrich and Bassler; Wright, pl. 1, figs. 30-32, (unpublished).

1951 *Cryptophyllus oboloides* (Ulrich and Bassler); Levinson, p. 558, pl. 77, figs. 9a-b.

?1951 *Schmidtella latimarginata* Keenan, pp. 563-564 *pars*, pl. 79, fig. 16, *non* figs. 7-8.

1956 *Cryptophyllus oboloides* (Ulrich and Bassler); Cornell, p. 23, pl. 6, figs. 13-17, (unpublished).

1956 *Cryptophyllus sulcatus* Levinson; Cornell, pp. 23-24, pl. 6, fig. 11, (unpublished).

?1957 *Cryptophyllus gibbosum* Harris, pp. 180-181, pl. 5, figs. 9a-c.

1957 *Cryptophyllus oboloides* (Ulrich and Bassler); Swain, p. 565, pl. 62, figs. 15a-f.

1961 *Cryptophyllus oboloides* (Ulrich and Bassler); Swain, Cornell and Hansen, p. 363, pl. 48, figs. 10a-b.

1961 *Cryptophyllus oboloides* (Ulrich and Bassler); Levinson and Moore *in* Moore, pp. Q189-Q191, figs. 132.8a-b.

?1962 *Cryptophyllus sulcatus* Levinson; Guber, pp. 93-94 *pars*, pl. 3, fig. 6, *non* fig. 7, (unpublished).

?1968 *Cryptophyllus gutta* Schallreuter, p. 110, pl. 13, figs. 4-7.

1971 *Cryptophyllus oboloides* (Ulrich and Bassler); Copeland *in* Steele and Sinclair, p. 42, pl. 23, fig. 2.

1972 *Cryptophyllus oboloides* (Ulrich and Bassler); Bolton and Copeland, pl. A, fig. 3.

1973 *Cryptophyllus* sp. cf. *Cryptophyllus oboloides* (Ulrich and Bassler); Copeland, pp. 21-22, pl. 6, fig. 15.

1974 *Cryptophyllus oboloides* (Ulrich and Bassler); Copeland, p. 27, pl. 3, figs. 9-10.

?1974a *Cryptophyllus halyei* Copeland, p. 47, pl. 9, fig. 15.

?1974a *Cryptophyllus noeli* Copeland, p. 48, pl. 11, figs. 5-8.

1982 *Cryptophyllus oboloides* (Ulrich and Bassler); Copeland, pl. 7, fig. 2; pl. 9, fig. 2.

1982 *Cryptophyllus oboloides* (Ulrich and Bassler); Warshauer and Berdan, p. H67, pl. 17, figs. 1-3.

?1982 *Americoncha dubia* Warshauer and Berdan, pp. H66-H67, pl. 17, figs. 13-29.

Holotype.- *Eridoconcha oboloides* Ulrich and Bassler 1923a, p. 297, fig. 14, nos. 6-8.

Diagnosis.- See Levinson (1951, p. 558).

Description.- Valves subtriangular and dorsally umbonate. Anterior and posterior margins evenly curved and at about 90° to each other. Ventral margin gently curved. HV at about mid-length, LV just below mid-height, WV at about mid-height. Hinge

sunken between umbones. Dorsally, umbones have a poorly developed S2. Surface smooth with two concentric ridges, reflecting retained moults.

Measurements.- LV 850 μ, 775 μ, 675 μ, 600 μ, 525 μ.
HV 700 μ, 625 μ, 550 μ, 450 μ, 425 μ.

Remarks.- *Cryptophyllus oboloides* is common in Middle Ordovician strata throughout North America. More material is needed in order to ascertain how variable the number of moults retained in *Cryptophyllus oboloides*, really is.

Material.- Five well-preserved valves from samples (A-7, A-15) and seven somewhat corroded valves from samples (L-4, L-9).

Occurrence.- Black Duck (L-4) and Beach Point (L-9) members, Lourdes Formation western Newfoundland. Ellis Bay Formation, Members 1 (A-7) and 4 (A-15), Anticosti Island.

***Cryptophyllus* sp. aff. *C. oboloides* (Ulrich and Bassler 1923)**

Pl. 15, figs. 10-11; text-fig. 23c.

Synonymy.- **1957** *Schmidtella latimarginata* Keenan; Carter, pp. 93-94, pl. 4, figs. 7a-c, (unpublished).
1982 *Cryptophyllus* sp. Warshauer and Berdan, p. H67, pl. 17, figs. 4-6.
1988 *Cryptophyllus* sp. Berdan, pp. 290-291, pl. 2, figs. 7-8.

Description.- Valves subovate. HV at about mid-length, LV at about mid-height. Dorsal margin slightly indented at umbo, ventral margin gently rounded; anterior and posterior margins evenly rounded. Surface smooth with two concentric ridges that reflect the retained moults.

Measurements.- LV 725 μ, 700 μ, 675 μ, 625 μ, 625 μ.
HV 500 μ, 500 μ, 475 μ, 450 μ, 450 μ.

Remarks.- *Cryptophyllus* sp. aff. *Cryptophyllus oboloides* differs from the type species *Cryptophyllus oboloides* in being more elongate and having only two retained moults; it is not certain whether these two species are synonymous.

Material.- Twenty-nine valves, most of the specimens appear to be internal moulds.

Occurrence.- Deschambault Formation (S-4, S-10, S-16, S-17, S-18) Laurentides, Sorel and Grondines map-areas, St. Lawrence Lowlands.

Order PODOCOPIDA Muller 1884

(*nom. correct.* Pokorný 1953)

Diagnosis.- See Sylvester-Bradley *in* Moore (1961, p. Q197).

Remarks.- The Order Podocopida (Ordovician-Recent) is a large, diverse group of ostracodes that includes all living freshwater ostracodes and the vast majority of modern marine ostracodes. Sars (1866) established the Podocopa (which later became the Podocopida) on the basis of the appendages of modern ostracodes. Unfortunately, these soft parts are not preserved in the fossil record and identification of fossil palaeocopids is largely based on the nature of muscle scar patterns, valve shape, sculpture and overlap. Because podocopids often lack distinctive morphological features, they are often known informally as "smooth forms" or "non-palaeocopes". In addition to discussing the differences between the podocopids and platycopids, Maddocks (1982, pp. 230-231) comments on the modes of life of the podocopids.

Suborder METACOPINA Sylvester-Bradley 1961

Diagnosis.- See Sylvester-Bradley *in* Moore (1961, pp. Q358-Q359).

Remarks.- The metacopines are podocopids which have simple hinge structures, compound muscle scar patterns and a poorly developed inner lamella. For further discussion of the metacopines see Scott *in* Moore (1961, pp. Q88-Q89).

Superfamily HEALDIACEA Harlton 1933

(*nom. transl.* Madelstam 1960)

Diagnosis.- See Shaver *in* Moore (1961, p. Q359).

Family BAIRDIOCYPRIDIDAE Shaver 1961

Diagnosis.- See Shaver *in* Moore (1961, pp. Q364-Q365).

Genus *Phelobythocypris* Warshauer and Berdan 1982

Type species.- *Leperditia (Isochilina) cylindrica* Hall 1871

Diagnosis.- See Warshauer and Berdan (1982, pp. H68-H69).

Occurrence.- Known from the Middle to Upper Ordovician of North America, (Warshauer and Berdan 1982).

Phelobythocypris cylindrica (Hall 1871)

Pl. 16, figs. 1-2; text-fig. 23d.

Synonymy.-

1871 *Leperditia (Isochilina) cylindrica* Hall, p. 27, pl. 8, fig. 12.
1872 *Leperditia (Isochilina) cylindrica* Hall; Hall, p. 231, pl. 8, fig. 12.
1875 *Leperditia (Isochilina) cylindrica* Hall; Hall and Whitfield, p. 101, pl. 4, fig. 5.
?1889 *Bythocypris cylindrica* (Hall); Ulrich, p. 48, pl. 9, fig. 6.
1889 *Leperditia subcylindrica* Ulrich, p. 49, pl. 9, figs. 4-4b.
?1894 *Bythocypris cylindrica* (Hall); Ulrich, p. 687, pl. 44, figs. 29-35.
1919 *Bythocypris cylindrica* (Hall); Bassler, p. 405, pl. 55, figs. 28-31.
1924 *Bythocypris cylindrica* (Hall); Foerste, p. 255, pl. 46, fig. 2.
?1928 *Bythocypris cylindrica* (Hall); Bassler *in* Twenhofel, p. 350, (not figured).
?1939 *Bythocypris batesi* Spivey, p. 173, pl. 21, figs. 51-54.
?1940 *Bythocypris cylindrica* (Hall); Kay, p. 268, (not figured).
?1941 *Bythocypris* aff. *Bythocypris cylindrica* (Hall); Roy, p. 176, figs. 146a-b.
1944 *Bythocypris cylindrica* (Hall); Shimer and Shrock, p. 683, pl. 287, figs. 46-49.
1951 *Bythocypris cylindrica* (Hall); Keenan, p. 567, pl. 78, figs. 4, 8-13.

1956 *Bythocypris cylindrica* (Hall); Cornell, pp. 59-60, pl. 16, figs. 1-5, (unpublished).

1957 *Bythocypris cylindrica* (Hall); Carter, pp. 248-250, pl. 13, figs. 7a-d, (unpublished).

?1957 *Bythocypris? extenuata* (Hall); Carter, pp. 250-251, pl. 13, figs. 5a-d, (unpublished).

1957 *Bythocypris cylindrica* (Hall); Harris, pp. 258-259, pl. 10, figs. 11a-c, 12.

?1957 *Bythocypris* sp. cf. *Bythocypris granti* Ulrich; Harris, pp. 259-260, pl. 10, figs. 13a-b.

1965 *Bythocypris? cylindrica* (Hall); Copeland, p. 45, pl. 2, figs. 2-4.

1970 "*Bythocypris*" *cylindrica* (Hall); Copeland, p. 23, pl. 4, fig. 25.

?1970 "*Bythocypris*" *subcylindrica* (Ulrich); Copeland, p. 23, pl. 4, fig. 26.

?1971 *Bythocypris? cylindrica* (Hall); Copeland *in* Steele and Sinclair, pl. 23, fig. 1.

1972 "*Cytherellina cylindrica*" (Hall); Warshauer, p. 188, pl. 7, fig. 19, (unpublished).

1973 "*Bythocypris*" *cylindrica* (Hall); Copeland, pl. 2, figs. 5, 7; pl. 3, fig. 38; pl. 4, fig. 2.

?1973 "*Bythocypris*" *subcylindrica* (Ulrich); Copeland, pl. 2, fig. 1; pl. 4, figs. 3, 5.

?1974 *Bairdiocypris cylindrica* (Hall); Copeland, pl. 6, fig. 7.

1974a "*Bythocypris*" sp. cf. "*Bythocypris*" *cylindrica* (Hall); Copeland, p. 50, pl. 8, figs. 1-3.

1977c *Bairdiocypris cylindrica* (Hall); Copeland, pl. 3, figs. 7, 9.

?1977c *Bairdiocypris* sp. Copeland, pl. 6, fig. 6.

1982 *Phelobythocypris cylindrica* (Hall); Warshauer and Berdan, pp. H68-H69, pl. 18, figs. 8-18.

1987 *Elliptocyprites paracylindrica* Swain and Cornell, p. 114, pl. 10, figs. 3a-e.

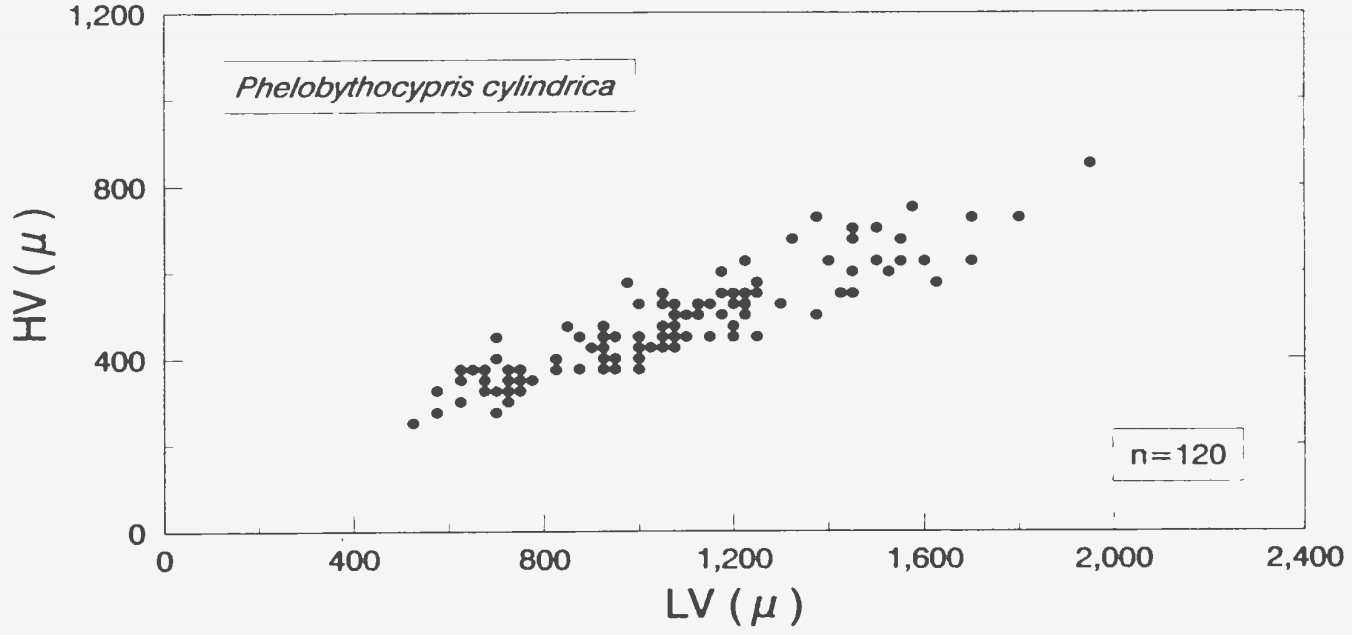
Holotype.- *Leperditia (Isochilina) cylindrica* Hall 1871, p. 27, pl. 8, fig. 12.

Diagnosis.- See Warshauer and Berdan (1982, p. H68).

Description.- Valves elongate, and subelliptical to subreniform in outline. Cross-section subovate. Dorsal margin evenly to asymmetrically curved, ventral margin

straight to slightly concave. LV at about mid-height, HV and WV posterior of mid-length. Long, simple, grooved hinge. Slightly larger left valve, overlaps right valve around free margin. Surface smooth.

Measurements.- The specimens of *Phelobythocypris cylindrica* exhibit continuous size variation, but show some signs of instar development (Text-fig. 25).



Text-fig. 25. Size dispersion diagram of *Phelobythocypris cylindrica* (Hall 1871) from samples A-2, A-3, A-4, A-5, A-6, A-8, A-7, A-9, A-10, A-13, A-14, A-15 and A-16.

Remarks.- Until Warshauer and Berdan's (1982) description of *Phelobythocypris*, most reniform Paleozoic ostracodes were assigned to the Holocene genus, *Bythocypris* Brady 1880. Warshauer and Berdan (1982) established *Phelobythocypris*, because although the Holocene and Paleozoic taxa are superficially similar, the later lack the duplicature and muscle scars which are so distinctive of the former. *Bythocypris*

lindstroemi Jones 1890 and *Bythocypris subcylindrica* (Ulrich 1889) are similar to *Phelobythocypris cylindrica* and these taxa are, at least in part synonymous.

Material.- Twenty-two valves and about one hundred and sixty-five carapaces; all the specimens are well preserved.

Occurrence.- Vauréal Formation (A-2, A-3, A-4, A-5, A-6, A-8) and Members 1 (A-7, A-9), 2 (A-10, A-13), 3 (A-11), 4 (A-14, A-15) and 5 (A-12, A-16), Ellis Bay Formation, Anticosti Island.

Family KRAUSELLIDAE Berdan 1961

Diagnosis.- See Berdan *in* Moore (1961, p. Q371).

Genus *Krausella* Ulrich 1894

Type species.- *Krausella inaequalis* Ulrich 1894

Diagnosis.- See Ulrich (1894, p. 691), Berdan *in* Moore (1961, pp. Q371-Q373) and Kraft (1962, p. 63).

Remarks.- Swain (1962, p. 738) considers *Basslerites* Teichert 1937 and *Rayella* Teichert 1939 to be junior synonyms of *Krausella* Ulrich 1894.

Occurrence.- Known from the Middle Ordovician to Lower Devonian of North America and Europe, (Berdan *in* Moore 1961, pp. Q371-Q373).

Krausella arcuata Ulrich 1894

Pl. 16, fig. 3; text-fig. 23e.

Synonymy.-
1894 *Krausella arcuata* Ulrich, pp. 692-693, pl. 44, figs. 47-53.
?1894 *Krausella inaequalis* Ulrich, p. 692, pl. 44, figs. 44-46.
1931 *Krausella arcuata* Ulrich; Harris, p. 94, pl. 14, figs. 4a-c.
?1940 *Krausella curtispina* Kay, p. 267, pl. 34, figs. 35-37.
?1940 *Krausella arcuata* Ulrich; Kay, p. 267, (not figured).
?1940 *Rayella calvini* Kay, p. 268, pl. 34, figs. 32-34.

?1941 *Krausella* sp. cf. *Krausella inaequalis* Ulrich; Roy, p. 175, figs. 144a-b.

?1944 *Krausella inaequalis* Ulrich; Shimer and Shrock, p. 682, pl. 286, figs. 48-50.

1944 *Krausella arcuata* Ulrich; Shimer and Shrock, p. 682, pl. 286, figs. 51-55.

?1951 *Rayella brevicornis* Keenan, pp. 567-568, pl. 79, figs. 40-41.

1952 *Krausella arcuata* Ulrich; Moore, Lalicker and Fischer, p. 525, fig. 14.2, nos. 5a-b.

1956 *Krausella arcuata* Ulrich; Cornell, pp. 57-58, pl. 15, figs. 7a-b, (unpublished).

1957 *Krausella arcuata* Ulrich; Carter, pp. 241-242, pl. 12, figs. 5a-e, (unpublished).

1957 *Rayella parvispina* Carter, pp. 243-245, pl. 12, figs. 4a-e, (unpublished).

?1957 *Rayella calvini* Kay; Harris, pp. 254-255, pl. 10, figs. 6a-c.

1962 *Krausella variata* Kraft, pp. 63-66, pl. 17, figs. 1-23; pl. 18, figs. 1a-b: text-figs. 14m, 15a-b.

?1965 *Krausella calvini* (Kay); Copeland, p. 46, pl. 2, figs. 8-9.

1965 *Krausella* sp. cf. *Krausella arcuata* Ulrich; Copeland, p. 47, pl. 3, figs. 11-13.

1966 *Pseudorayella admirabilis* Neckaja, pl. 12, no. 7.

1970 *Krausella* sp. cf. *Krausella arcuata* Ulrich; Copeland, pp. 23-24, pl. 4, fig. 29.

1971 *Krausella arcuata* Ulrich; Copeland *in* Steele and Sinclair, pl. 23, fig. 9.

?1971 *Krausella calvini* Kay; Copeland *in* Steele and Sinclair, pl. 23, figs. 10-13.

1972 *Krausella* sp. cf. *Krausella arcuata* Ulrich; Bolton and Copeland, pl. A, fig. 5.

?1972 *Krausella* sp. Warshauer, p. 196, pl. 2, fig. 13, (unpublished).

1974 *Krausella?* sp. cf. *Krausella? acuta* (Teichert); Copeland, p. 29, pl. 6, figs. 3-5, 17-19.

1977c *Krausella?* sp. cf. *Krausella? acuta* (Teichert); Copeland, pl. 3, figs. 1-4; pl. 5, fig. 4.

?1977c *Krausella* sp. Copeland, pl. 6, fig. 5.

?1987 *Krausella variata* Kraft; Swain and Cornell, p. 114, pl. 10, fig. 4.

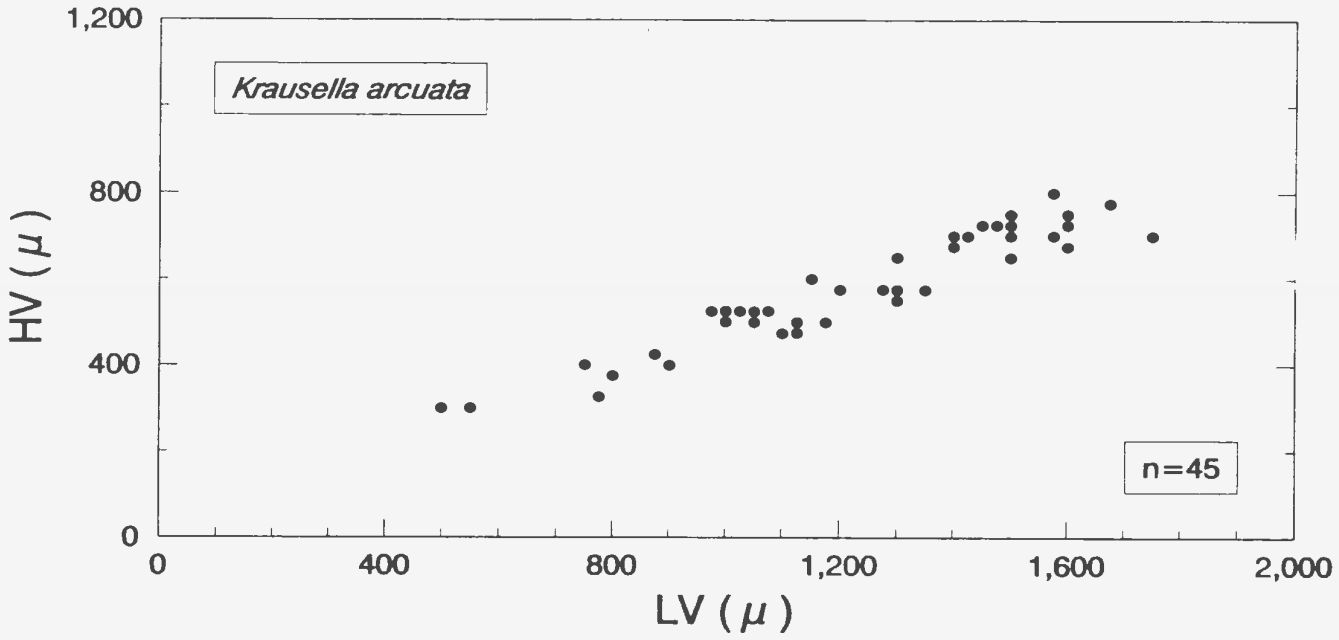
1987 *Krausella arcuata* Ulrich; Swain and Cornell, p. 114, pl. 10, figs. 5a-c.

Holotype.- *Krausella arcuata* Ulrich 1894, pp. 692-693, pl. 44, figs. 47-53.

Diagnosis.- See Ulrich (1894, pp. 692-693) and Swain and Cornell (1987, p. 114).

Description.- Valves elongate and subelliptical in outline. Dorsal margin gently arched, ventral margin nearly straight. Anterior margin broadly rounded, posterior margin of right valve produced and bluntly pointed. LV below mid-height, HV at about mid-length. Inequivalved, larger right valve overlaps left valve around entire margin except in the hinge area. Valves evenly swollen. Surface smooth.

Measurements.- The specimens of *Krausella arcuata* exhibit continuous size variation (Text-fig. 26). There are signs of instar development, but more specimens are needed to define these instar patterns.



Text-fig. 26. Size dispersion diagram of *Krausella arcuata* Ulrich 1894 from sample S-20.

Remarks.- Krausellids like *Krausella arcuata* exhibit a high degree of intraspecific variability (Kraft 1962, p. 65) and several species like *Krausella inaequalis* Ulrich

1894, *Krausella arcuata* Ulrich 1894, *Krausella rawsoni* Kay 1940 and *Krausella variata* Kraft 1962 grade imperceptibly into one another, creating considerable taxonomic confusion (Copeland 1974, p. 28). Clarification of the relationships between the various Ordovician krausellids awaits further study and taxonomic revision.

Material.- The Carter Collection (Redpath Museum), contains at least several hundred well-preserved calcified carapaces and valves. Only the forty-six carapaces and valves from sample (S-20) were examined in detail.

Occurrence.- Black River and Trenton groups at numerous localities in the Laval, Sorel, Yamaska, Trois-Rivières, Grondines, Portneuf and St. Raymond map-areas, St. Lawrence Lowlands, (see Carter 1957, pp. 241-242 for details). Described specimens from the Leray Formation (S-20), St. Raymond map-area, St. Lawrence Lowlands.

Family PACHYDOMELLIDAE Berdan and Sohn 1961

Diagnosis.- See Berdan and Sohn *in* Moore (1961, p. Q373).

Genus *Tubulibairdia* Swartz 1936

Type species.- *Tubulibairdia tubulifera* Swartz 1936

Diagnosis.- See Swartz (1936, p. 581) and Berdan and Sohn *in* Moore (1961, p. Q373).

Occurrence.- Known from the Upper Ordovician to Middle Devonian of eastern North America and central Europe, (Berdan and Sohn *in* Moore 1961, p. Q373).

Tubulibairdia jolieti Copeland 1973

Pl. 16, figs. 4-6; text-fig. 23f.

Synonymy.- ?1890 *Pachydomella tumida* Ulrich, p. 198, figs. 5a-c.
?1970 *Tubulibairdia* sp. Copeland, p. 25, pl. 5, fig. 9.

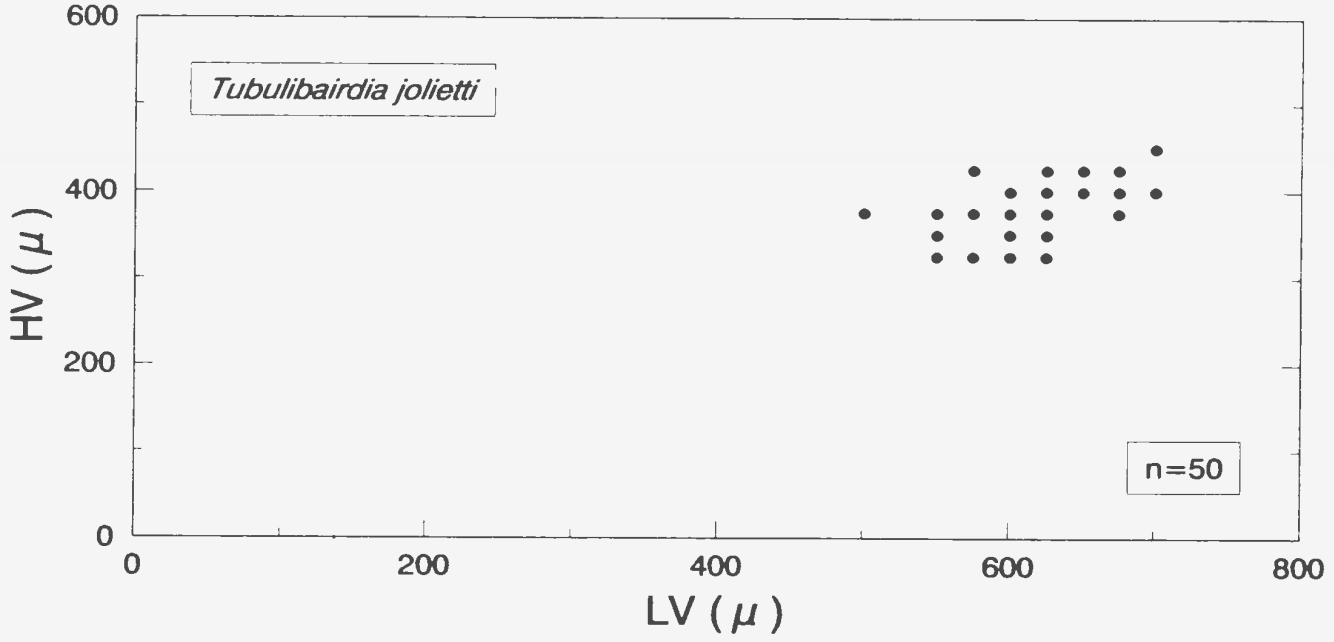
1973 *Tubulibairdia jolieti* Copeland, p. 24, pl. 1, fig. 4; pl. 3, figs. 1-4; pl. 4, fig. 1; pl. 5, figs. 9-10; pl. 6, fig. 8.

Holotype.- *Tubulibairdia jolieti* Copeland 1973, p. 25, pl. 1, fig. 4.

Diagnosis.- See Copeland (1973, p. 25).

Description.- Carapace kidney-shaped in lateral view and lemon-shaped in dorsal and ventral views. Dorsal margin arched, shoulders merging into narrowly curved anterior and posterior margins, ventral margin medially concave. LV just below mid-height, HV at mid-length. Inequivalved, larger left valve overlaps smaller right valve around the entire margin, except posteroventrally. Short, mid to posterodorsal hinge, sunken between raised dorsal shoulders of both valves. Posteroventral margin flattened. Surface granular and usually coarsely punctate.

Measurements.- All the specimens of *Tubulibairdia jolietti* are roughly the same size (Text-fig. 27). No instar patterns are recognisable and the assemblage is probably size-sorted.



Text-fig. 27. Size dispersion diagram of *Tubulibairdia jolieti* Copeland 1973 from samples A-7, A-9, A-11, A-14, A-15 and A-16.

Remarks.- *Tubulibairdia jolieti* is similar to the species *Microcheilinella anticostiensis* and *Pachydomella wolfei*, that were described from the Silurian of Anticosti Island by Copeland (1974a). Taxa assigned to the genus *Punctoschmidtella* Berdan 1989 which was recently described by Berdan (1989, pp. 287-289) are also similar to *Tubulibairdia jolieti*.

Material.- Sixty-five carapaces and eleven valves; all the specimens have their original shell material preserved.

Occurrence.- Members 1 (A-7, A-9), 3 (A-11), 4 (A-14, A-15) and 5 (A-16), Ellis Bay Formation, Anticosti Island.

Family QUASILLITIDAE Coryell and Malkin 1936

Diagnosis.- See Sohn and Stover *in* Moore (1961, pp. Q374-375).

Genus *Eographiodactylus* Kraft 1962

Type species.- *Eographiodactylus eos* Kraft 1962

Diagnosis.- See Kraft (1962, pp. 62-63).

Occurrence.- Known from the Middle and Upper Ordovician of Europe and eastern North America, (Kraft 1962, pp. 62-63).

Eographiodactylus hyatti Copeland 1973

Pl. 16, fig. 7; text-fig. 23g.

Synonymy.- ?1970 *Eographiodactylus billingsi* Copeland, p. 19, pl. 4, figs. 6-9, 15, 19.

1973 *Eographiodactylus hyatti* Copeland, pp. 24-25, pl. 3, figs. 25-28; pl. 4, figs. 18-21.

Holotype.- *Eographiodactylus hyatti* Copeland 1973, pp. 24-25, pl. 4, fig. 19.

Diagnosis.- See Copeland (1973, pp. 24-25).

Description.- Valves subquadrate and preplete. HV anterior of mid-length, LV at about mid-height. Dorsal margin nearly straight, ventral margin slightly convex. Anterior margin smoothly rounded, posterior margin bluntly subrounded. Anterior cardinal angle about 130°, posterior cardinal angle formed into a blunt spine. Bilobate, L1 and L2 poorly developed. S2 a shallow depression near mid-length. Lateral surface reticulate; reticulae regularly arranged centrally, becoming more linear marginally. Narrow velar ridge extends from anterodorsal corner to the posteroventral border where it ends as a blunt spine. Subvelar field shallow. Thin marginal ridge.

Measurements.- LV 825 μ, 675 μ.
HV 425 μ, 375 μ.

Remarks.- Although *Eograph*iodactylus *billingsi* differs from *Eograph*iodactylus *hyatti* in having a smooth ornament, it is otherwise similar and the two taxa are tentatively included in synonymy. Schallreuter (1980, pp. 1-8) discusses the adventral structure of *Eograph*iodactylus *billingsi* and *Eograph*iodactylus *hyatti*.

Material.- Three valves; the specimens are delicate and not particularly well preserved.

Occurrence.- Members 3 (A-11) and 4 (A-15), Ellis Bay Formation, Anticosti Island.

Superfamily UNCERTAIN

Family UNCERTAIN

Genus *Balticella* Thorslund 1940

Type species.- *Balticella oblonga* Thorslund 1940

Diagnosis.- See Moore *in* Moore (1961, p. Q407).

Remarks.- The familial affinities of *Balticella* were considered uncertain in the *Treatise* (Moore 1961, p. Q407). Later authors, like Kraft (1962, p. 57) and Swain (1962, p. 738) have included *Balticella* with the kloedenellids. See Schallreuter (1968a, pp. 135-137) for further discussion of the taxonomic affinities of *Balticella*.

Occurrence.- Known from the Ordovician of Europe and North America, (Moore *in* Moore 1961, p. Q407).

***Balticella deckeri* (Harris 1931)**

Pl. 16, figs. 8-9; text-fig. 23h.

Synonymy.-
- **1931** *Leperditella? deckeri* Harris, p. 89, pl. 14, figs. 5a-c.
- 1937 *Kloedenia? deckeri* (Harris); Harris, pp. 4-5, figs. 28a-b.
- 1941 *Leperditella? deckeri* Harris; Triebel, p. 312, pl. 3, figs. 28a-b.
- **1957** *Balticella deckeri* (Harris); Harris, p. 242, pl. 8, figs. 7a-c.
- ?1957 *Balticella deckeri* subsp. *elongata* Harris, p. 242, pl. 8, fig. 8.
- 1961 *Balticella deckeri* (Harris); Moore *in* Moore 1961, p. Q407, figs. 332.3a-c.
- 1962 *Balticella deckeri* (Harris); Kraft, pp. 57-58, pl. 13, figs. 16-17; pl. 14, figs. 1-10; text-figs. 10f-h.
- 1962 *Balticella deckeri* (Harris); Swain, p. 738, pl. 111, fig. 12.
- 1977 *Balticella deckeri* (Harris); Swain, fig. 3, no. 2.
- ?1977a *Balticella* sp. Copeland; Copeland, pl. 1, fig. 7.
- 1985 *Balticella deckeri* (Harris); Schallreuter and Siveter, pl. 69, fig. 3.
- **1989** *Balticella deckeri* (Harris); Williams and Siveter, pp. 94-99, pl. 16.95, figs. 1-5; pl. 16.97, figs. 1-6.

Holotype.- *Leperditella? deckeri* Harris 1931, p. 89, pl. 14, figs. 5a-c.

Diagnosis.- See Harris (1931, p. 89 and 1957, p. 242) and Williams and Siveter (1989, pp. 94-99).

Description.- Valves elongate, subelliptical and dorsally truncate. Dorsal margin sinuous, ventral margin slightly convex. Anterior and posterior margins evenly rounded. Valves preplete; HV just anterior of mid-length, LV just above mid-height. Cardinal angles abrupt; anterior cardinal angle about 120°, posterior cardinal angle

about 100°. Inequivalved, left valve overlaps right valve, both valves strongly inflated. Prominent anteromedian horn-like node; surface surrounding node depressed. Distinctive, subvertical slit-like sulcus, immediately posterior of node. Surface smooth.

Measurements.- LV 1375 μ, 1325 μ.
HV 625 μ, 650 μ.

Remarks.- In his description of silicified material from Virginia, Kraft (1962) noted that *Balticella deckeri* is not dimorphic, but goes through a series of distinctive developmental stages during ecdysis. Kraft (1962) also described two new taxa, *Thomasatia marginovelata* and *Thomasatia carinata*, both of which are similar to *Balticella deckeri*.

Material.- Three carapaces, all reasonably well-preserved internal moulds.

Occurrence.- Beach Point Member (L-8), Lourdes Formation, western Newfoundland.

Genus *Steusloffina* Teichert 1937

Type species.- *Steusloffina ulrichi* Teichert 1937

Diagnosis.- See Teichert (1937b, p. 120), Hessland *in* Moore (1961, pp. Q411-Q412), Schallreuter (1968a pp. 137-138), and Qvale (1980, pp. 96-97).

Remarks.- The taxonomic position of *Steusloffina* was considered uncertain in the *Treatise* (Moore 1961, pp. Q411-Q412). After a detailed examination of the taxonomy of *Steusloffina*, Hessland and Adamczak (1974) concluded that *Steusloffina* was probably a podocopid, but that its more precise assignment should be left open. The genera *Balticella* and *Steusloffina* exhibit a number of morphological similarities such as shape, and are grouped together here.

Occurrence.- Known from the Middle to Upper Ordovician of Europe, Greenland and North America, (Hessland *in* Moore 1961, pp. Q411-Q412).

Steusloffina ulrichi Teichert 1937

Pl. 16, fig. 10; text-fig. 23i.

Synonymy.-
- **1937b** *Steusloffina ulrichi* Teichert, pp. 120-122, pl. 24, figs. 2-5.
- **1957** *Steusloffina albanensis* Carter, pp. 259-261, pl. 13, figs. 8a-d, (unpublished).
- ?1961 *Steusloffina cuneata* (Steusloff); Sohn, pp. 84-85, pl. 6, fig. 17.
- 1961 *Steusloffina ulrichi* Teichert; Hessland *in* Moore, fig. 332.12.
- ?1974 *Steusloffina cuneata* (Steusloff); Hessland and Adamczak, pp. 59-64, pl. 1, figs. 1-4; pl. 3, figs. 1-3; text-figs. 1-2.
- 1977a *Steusloffina ulrichi* Teichert; Copeland, pl. 1, fig. 11.
- 1977c *Steusloffina ulrichi* Teichert; Copeland, pl. 1, figs. 15-18; pl. 6, fig. 2.
- ?1983 *Steusloffina cuneata* (Steusloff); Copeland 1983, pp. 202-204, fig. 23.2.

Holotype.- *Steusloffina ulrichi* Teichert 1937b, pp. 120-122, pl. 24, figs. 2-5.

Diagnosis.- See Teichert (1937b, pp. 120-122).

Description.- Valves elongate, subelliptical and dorsally truncate. Dorsal margin arched near mid-length, ventral margin gently curved. Anterior margin broadly rounded, posterior margin more narrowly rounded. Valves preplete; HV just anterior of mid-length, LV just above mid-height. Anterior cardinal angle about 130°, posterior cardinal angle about 110°. Inequivalved, left valve overlaps right valve around entire free margin. Valves swollen dorsomedianly. No evidence of spines. Surface generally smooth, but faintly tuberculate posteriorly.

Measurements.- LV 1550 μ, 1450 μ.
HV 875 μ, 700 μ.

Remarks.- *Steusloffina ulrichi* is morphologically similar to *Steusloffina cuneata* (Steusloff 1895) and these two taxa are probably synonymous. See Hessland and Adamczak (1974) and Copeland (1983) for further discussion of the steusloffinids.

Material.- Four well-preserved calcified valves and one carapace, (Carter Collection, Redpath Museum).

Occurrence.- Lower Deschambault Formation (S-18), Grondines map-area, St. Lawrence Lowlands.

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PLATE 1

[all scale bars are 1000 μ]

Fig. 1. *Eoleperditia fabulites* (Conrad 1843)
Right valve, from the Black Duck Member, Lourdes Formation, western Newfoundland, sample L-7.

Fig. 2. *Bivia bivia* (White 1874)
Adult right valve, from the Table Point Formation, western Newfoundland, sample T-3.


1
2

PLATE 2

[all scale bars are 1000 μ]

Fig. 1. *Bivia bivia* (White 1874)
Adult right valve, from the Table Point Formation, western Newfoundland, sample T-3.

Fig. 2. *Bivia bivia* (White 1874)
Adult left valve, from the Table Point Formation, western Newfoundland, sample T-7.

Fig. 3. *Isochilina* sp.
Adult right valve, from the Beekmantown Group, St. Lawrence Lowlands, Carter Collection (S-9).

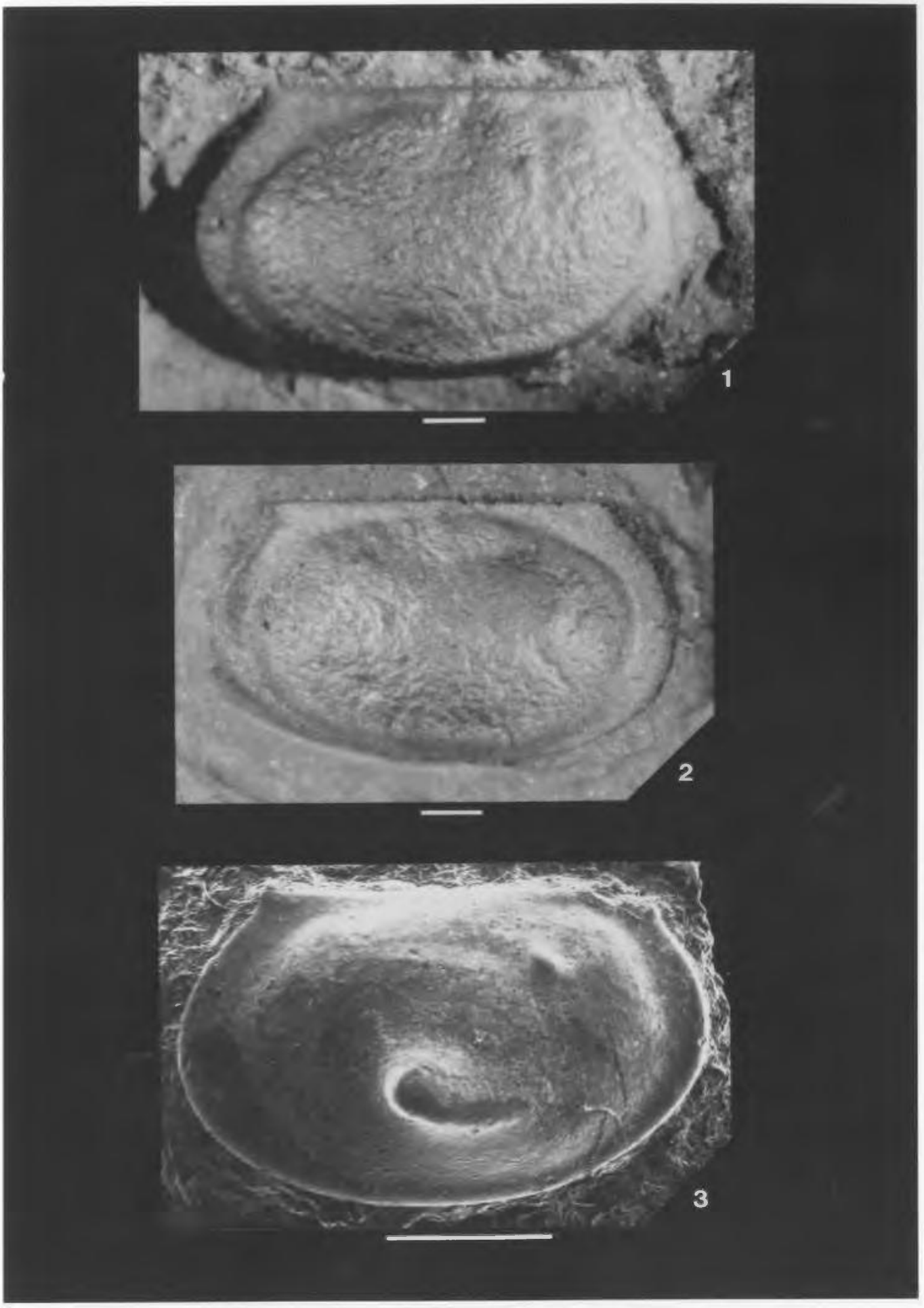
1
2
3

PLATE 3

[all scale bars are 300 μ]

Fig. 1. *Bolbiprimitia? schmitti* Copeland 1973
Right valve, from Member 4, Ellis Bay Formation, Anticosti Island, sample A-15.

Fig. 2. *Eurychilina reticulata* Ulrich 1889
Adult left valve, from the Deschambault Formation, St. Lawrence Lowlands, sample S-4.

Fig. 3. *Eurychilina reticulata* Ulrich 1889
Adult left valve, from the Deschambault Formation, St. Lawrence Lowlands, sample S-4.

Fig. 4. *Eurychilina reticulata* Ulrich 1889
Adult left valve, from the Deschambault Formation, St. Lawrence Lowlands, sample S-4.

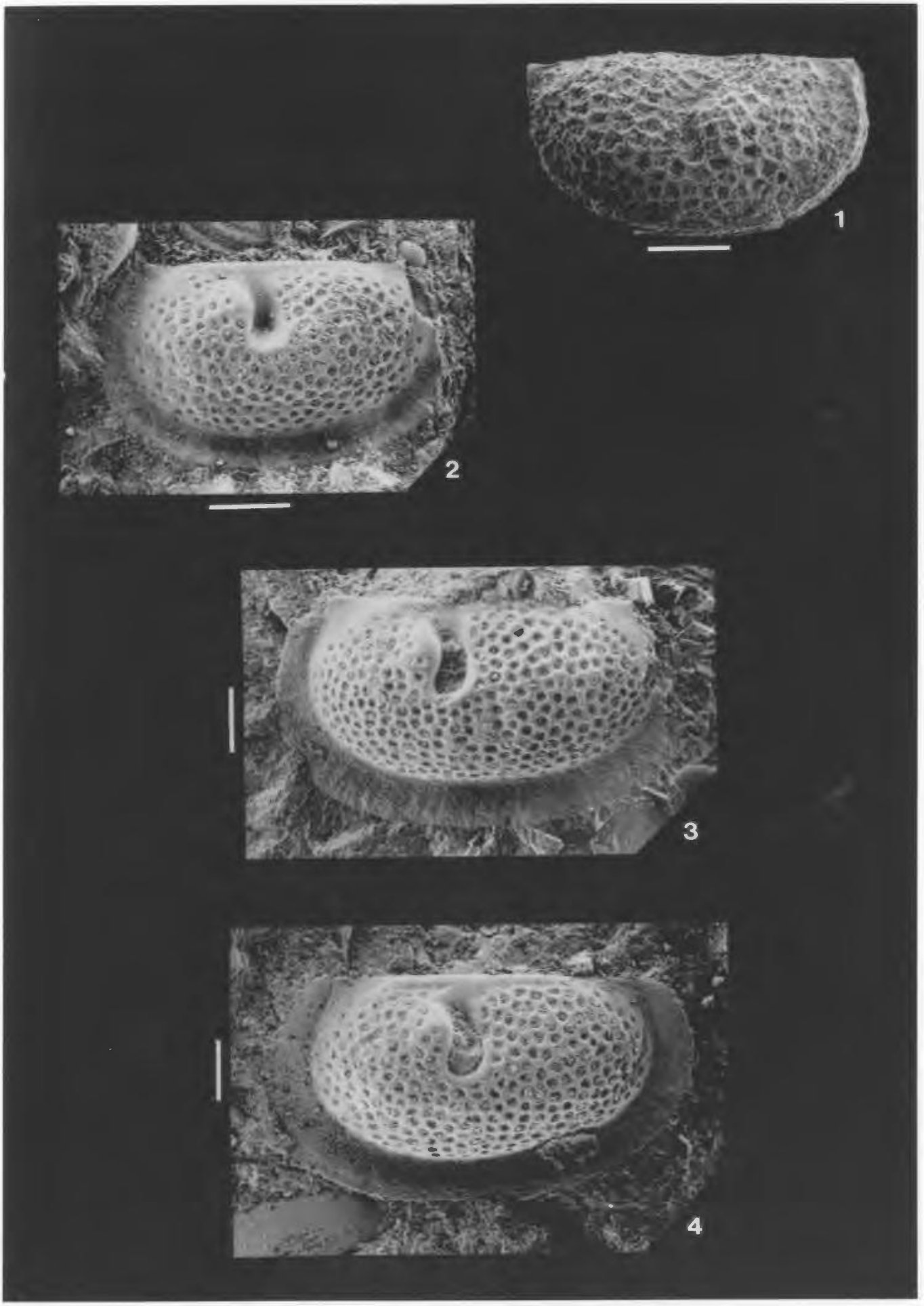
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PLATE 4

[all scale bars are 300 μ]

Fig. 1. *Eurychilina subradiata* Ulrich 1890
Oblique view of juvenile left valve, from the Deschambault Formation, St. Lawrence Lowlands, Carter Collection (S-15).

Fig. 2. *Eurychilina subradiata* Ulrich 1890
Adult left valve, from the Deschambault Formation, St. Lawrence Lowlands, sample S-4.

Fig. 3. *Eurychilina subradiata* Ulrich 1890
Adult right valve, from the Deschambault Formation, St. Lawrence Lowlands, sample S-4.

Fig. 4. *Eurychilina subradiata* Ulrich 1890
Adult left valve, from the Table Cove Formation, western Newfoundland, sample T-10.

Fig. 5. *Eurychilina subradiata* Ulrich 1890
Adult right valve, from the Table Cove Formation, western Newfoundland, sample T-11.

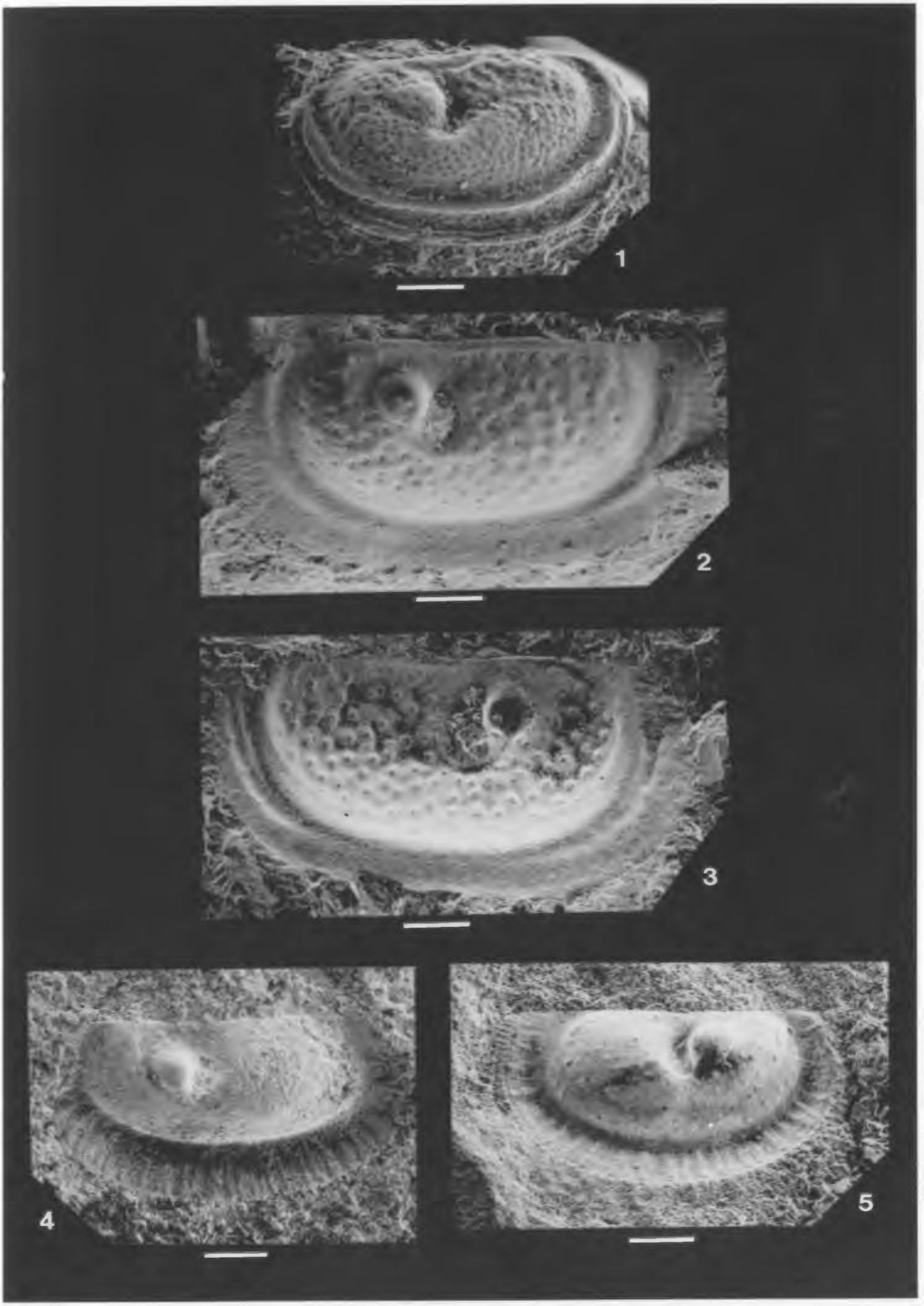
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PLATE 5

[all scale bars are 300 μ]

Fig. 1. *Eurychilina strasburgensis* Kraft 1962
Adult left valve, from the Deschambault Formation, St. Lawrence Lowlands, sample S-4.

Fig. 2. *Eurychilina strasburgensis* Kraft 1962
Adult right valve, from the Deschambault Formation, St. Lawrence Lowlands, sample S-4.

Fig. 3. *Coelochilina* sp.
Adult right valve, from the Deschambault Formation, St. Lawrence Lowlands, sample S-4.

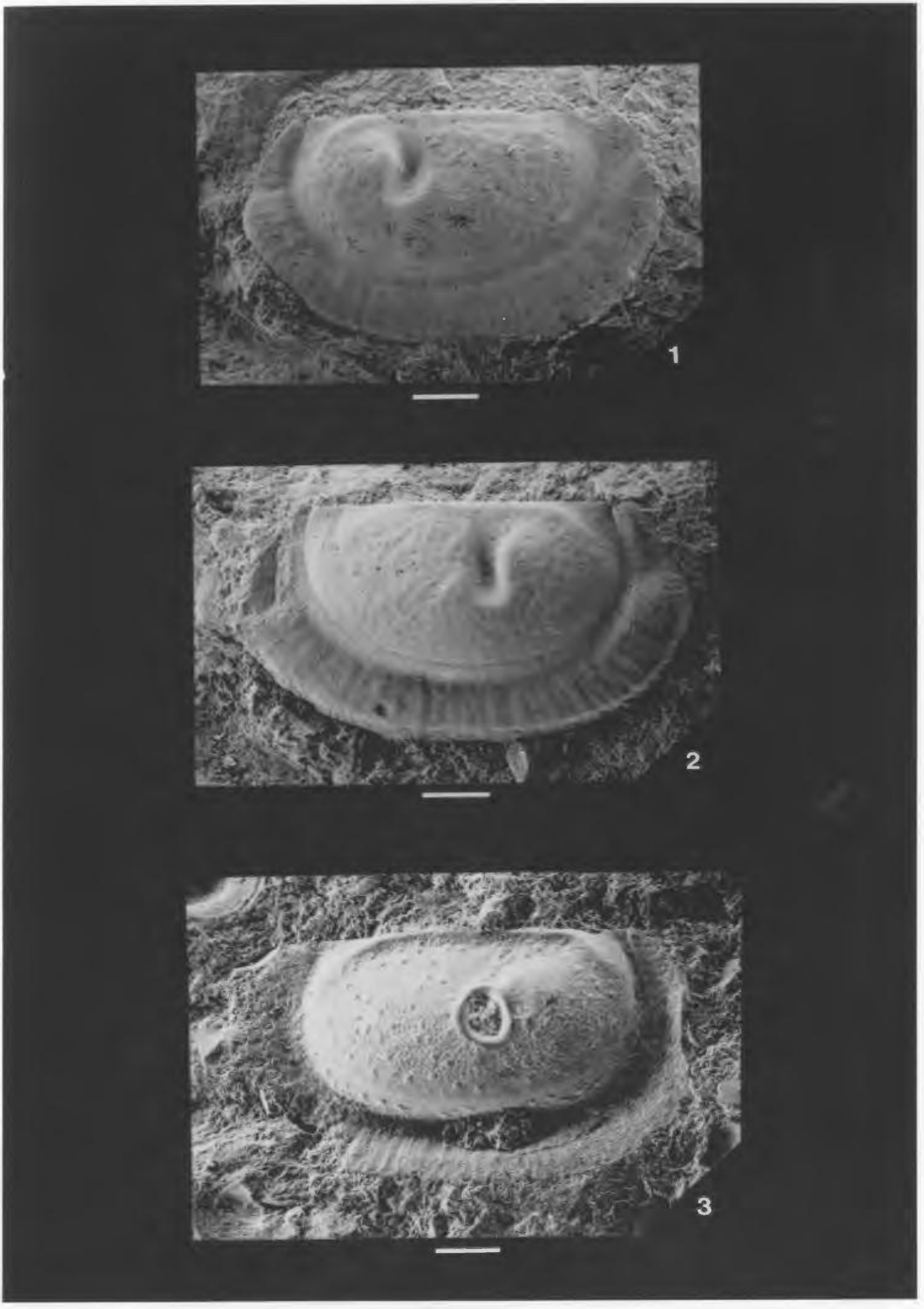
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PLATE 6

[all scale bars are 300 μ]

Fig. 1. *Coelochilina* sp.
Adult right valve, from the Deschambault Formation, St. Lawrence Lowlands, sample S-4.

Fig. 2. *Platybolbina shaleri* Copeland 1973
Adult right valve, from Member 5, Ellis Bay Formation, Anticosti Island, sample A-16.

Fig. 3. *Platybolbina shaleri* Copeland 1973
Valve, from Member 5, Ellis Bay Formation, Anticosti Island, sample A-16.

Fig. 4. *Platybolbina* sp.
Valve, from the Deschambault Formation, St. Lawrence Lowlands, Carter Collection (S-18).

Fig. 5. *Oepikium* sp. cf. *O. tenerum* (Öpik 1935)
Adult left valve, from the Deschambault Formation, St. Lawrence Lowlands, Carter Collection (S-7).

Fig. 6. *Euprimitia labiosa* (Ulrich 1894)
Left valve, from the Beach Point Member, Lourdes Formation, western Newfoundland, sample L-10.

Fig. 7. *Euprimitia labiosa* (Ulrich 1894)
Valve, from the Beach Point Member, Lourdes Formation, western Newfoundland, sample L-9.

Fig. 8. *Euprimitia?* sp.
Left valve, from the Deschambault Formation, St. Lawrence Lowlands, Carter Collection (S-10).

Fig. 9. *Euprimitia?* sp.
Right valve, from the Deschambault Formation, St. Lawrence Lowlands, sample S-4.

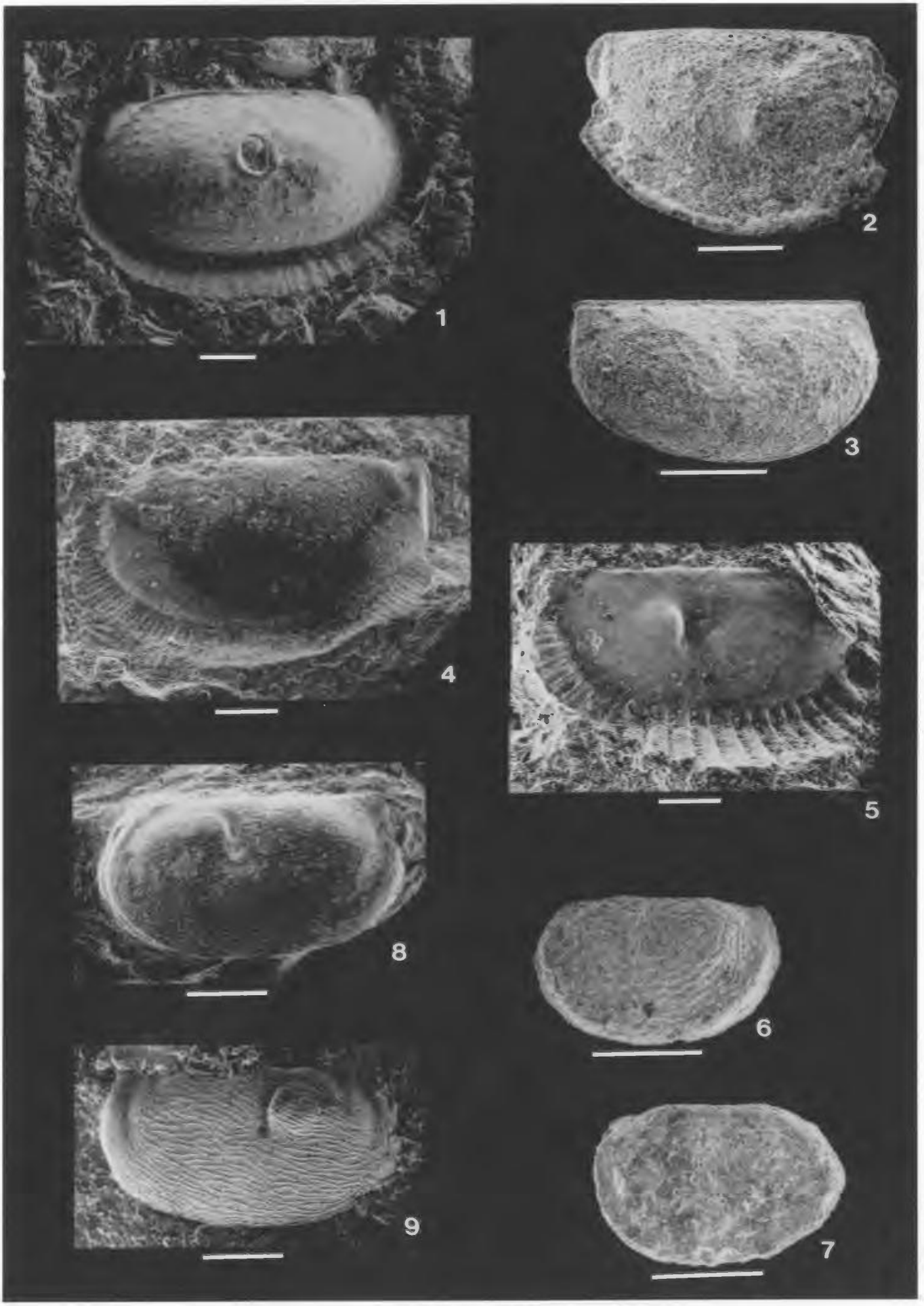
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PLATE 7

[all scale bars are 300 μ]

Fig. 1. *Sigmobolbina?* sp.
Right-lateral view of carapace, from the Beach Point Member, Lourdes Formation, western Newfoundland, sample L-8.

Fig. 2. *Winchellatia* sp.
Adult tecnomorphic left valve, from the Beach Point Member, Lourdes Formation, western Newfoundland, sample L-8.

Fig. 3. *Winchellatia* sp.
Juvenile right valve, from the Beach Point Member, Lourdes Formation, western Newfoundland, sample L-9.

Fig. 4. *Tetradella quadrilirata* (Hall and Whitfield 1875)
Adult heteromorphic right valve, from Member 1, Ellis Bay Formation, Anticosti Island, sample A-7.

Fig. 5. *Tetradella quadrilirata* (Hall and Whitfield 1875)
Oblique view of an adult heteromorphic right valve, from Member 1, Ellis Bay Formation, Anticosti Island, sample A-7.

Fig. 6. *Tetradella quadrilirata* (Hall and Whitfield 1875)
Adult heteromorphic right valve, from Member 5, Ellis Bay Formation, Anticosti Island, sample A-16.

Fig. 7. *Tetradella quadrilirata* (Hall and Whitfield 1875)
Ventral view of an adult heteromorphic right valve, from Member 5, Ellis Bay Formation, Anticosti Island, sample A-16.

Fig. 8. *Tetradella quadrilirata* (Hall and Whitfield 1875)
Adult heteromorphic right valve, from Member 5, Ellis Bay Formation, Anticosti Island, sample A-16.

Fig. 9. *Tetradella quadrilirata* (Hall and Whitfield 1875)
Juvenile right valve, from Member 5, Ellis Bay Formation, Anticosti Island, sample A-16.

Fig. 10. *Tetradella quadrilirata* (Hall and Whitfield 1875)
Juvenile left valve, from Member 5, Ellis Bay Formation, Anticosti Island, sample A-16.

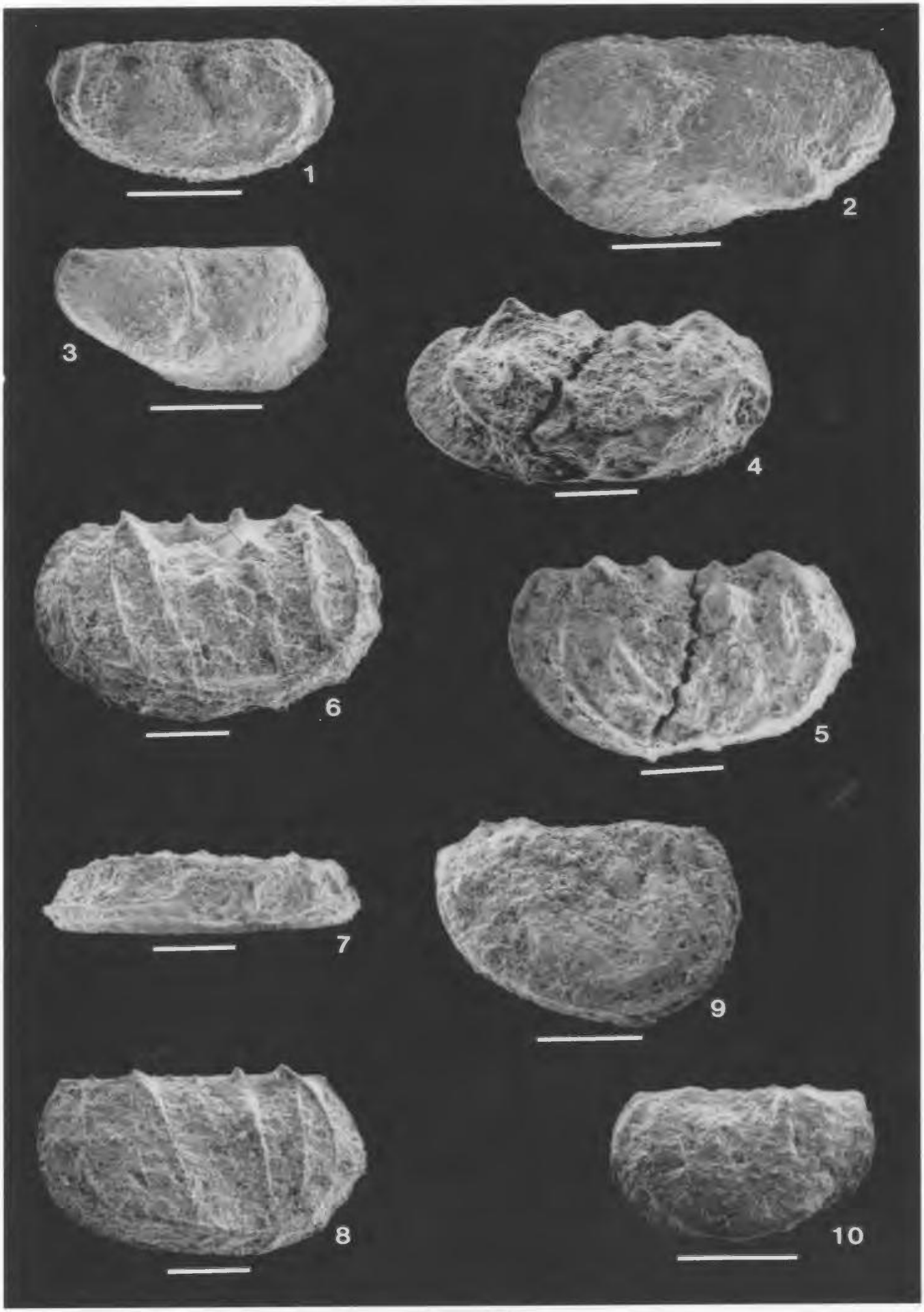
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PLATE 8

[all scale bars are 300 μ]

Fig. 1. *Tetradella? newfoundlandensis* Copeland 1977
Adult heteromorphic right valve, from the Beach Point Member, Lourdes Formation, western Newfoundland, sample L-10.

Fig. 2. *Tetradella? newfoundlandensis* Copeland 1977
Adult heteromorphic left valve, from the Beach Point Member, Lourdes Formation, western Newfoundland, sample L-8.

Fig. 3. *Tetradella? newfoundlandensis* Copeland 1977
Adult tecnomorphic left valve, from the Black Duck Member, Lourdes Formation, western Newfoundland, sample L-4.

Fig. 4 *Tetradella? newfoundlandensis* Copeland 1977
Adult tecnomorphic right valve, from the Black Duck Member, Lourdes Formation, western Newfoundland, sample L-4.

Fig. 5. *Tetradella? newfoundlandensis* Copeland 1977
Juvenile left valve, from the Black Duck Member, Lourdes Formation, western Newfoundland, sample L-4.

Fig. 6. *Foramenella phippsi* Copeland 1973
Right-lateral view of an adult heteromorphic carapace, from Member 5, Ellis Bay Formation, Anticosti Island, sample A-16.

Fig. 7. *Foramenella phippsi* Copeland 1973
Adult heteromorphic left valve, from Member 2, Ellis Bay Formation, Anticosti Island, sample A-13.

Fig. 8. *Foramenella phippsi* Copeland 1973
Ventral view of an adult heteromorphic carapace, from Member 1, Ellis Bay Formation, Anticosti Island, sample A-7.

Fig. 9. *Foramenella phippsi* Copeland 1973
Left-lateral view of an adult tecnomorphic carapace, from Member 5, Ellis Bay Formation, Anticosti Island, sample A-16.

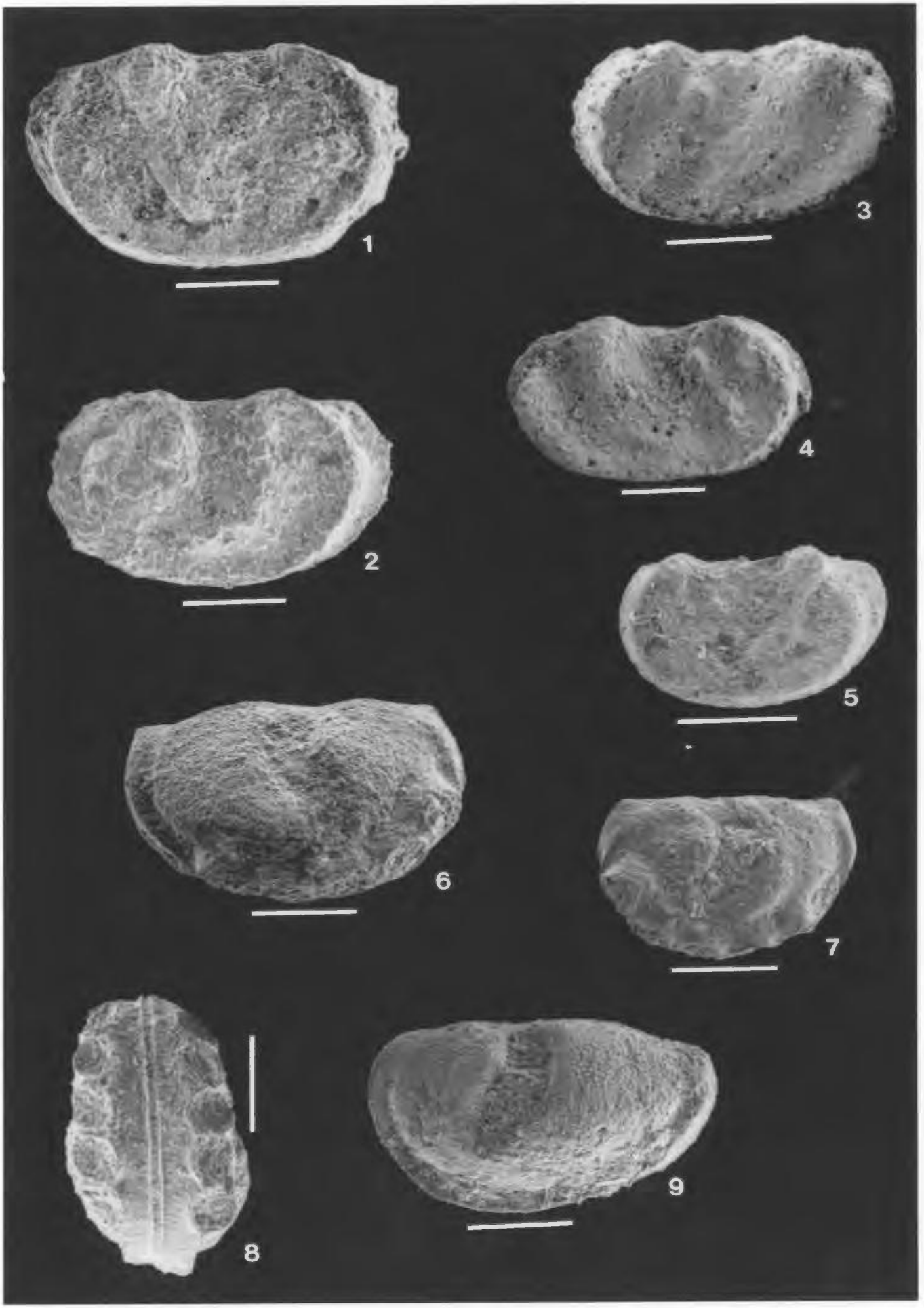
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PLATE 9

[all scale bars are 300 μ]

Fig. 1. *Foramenella phippsi* Copeland 1973
Adult tecnomorphic left valve, from Member 2, Ellis Bay Formation, Anticosti Island, sample A-13.

Fig. 2. *Foramenella phippsi* Copeland 1973
Adult tecnomorphic left valve, from Member 5, Ellis Bay Formation, Anticosti Island, sample A-16.

Fig. 3. *Foramenella phippsi* Copeland 1973
Adult tecnomorphic left valve, from Member 2, Ellis Bay Formation, Anticosti Island, sample A-13.

Fig. 4. *Anticostiella ellisensis* Copeland 1973
Tecnomorphic right valve, from Member 1, Ellis Bay Formation, Anticosti Island, sample A-7.

Fig. 5. *Anticostiella ellisensis* Copeland 1973
Heteromorphic left valve, from Member 1, Ellis Bay Formation, Anticosti Island, sample A-7.

Fig. 6. *Anticostiella ellisensis* Copeland 1973
Heteromorphic right valve, from Member 1, Ellis Bay Formation, Anticosti Island, sample A-7.

Fig. 7. *Anticostiella ellisensis* Copeland 1973
Heteromorphic right valve, from Member 4, Ellis Bay Formation, Anticosti Island, sample A-15.

Fig. 8. *Anticostiella ellisensis* Copeland 1973
Heteromorphic right valve, from Member 1, Ellis Bay Formation, Anticosti Island, sample A-7.

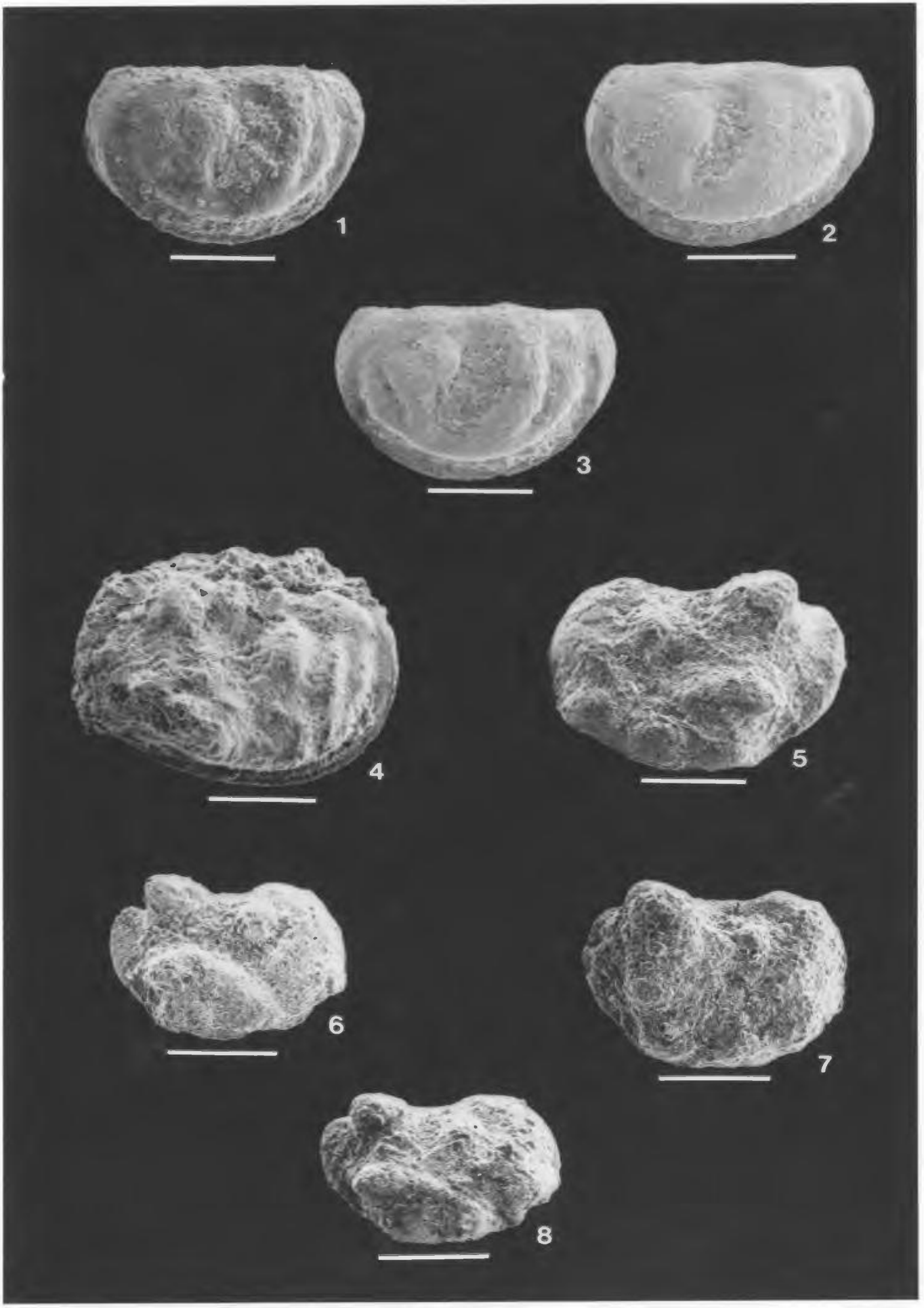
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PLATE 10

[all scale bars are 300 μ]

Fig. 1. *Tallinnella? subquadrans* (Ulrich 1890)
Right-lateral view of an adult carapace, from the Tétreauville Formation, St. Lawrence Lowlands, Carter Collection (S-12).

Fig. 2. *Tallinnella? subquadrans* (Ulrich 1890)
Dorsal view of an adult carapace, from the Tétreauville Formation, St. Lawrence Lowlands, Carter Collection (S-12).

Fig. 3. *Tallinnella? subqu..rans* (Ulrich 1890)
Right-lateral view of a juvenile carapace, from the Tétreauville Formation, St. Lawrence Lowlands, Carter Collection (S-8).

Fig. 4. *Tallinnella? subquadrans* (Ulrich 1890)
Juvenile left valve, from the Tétreauville Formation, St. Lawrence Lowlands, Carter Collection (S-8).

Fig. 5. *Ctenobolbina ciliata* (Emmons 1855)
Adult tecnomorphic left valve, from the Tétreauville Formation, St. Lawrence Lowlands, sample S-2.

Fig. 6. *Ctenobolbina ciliata* (Emmons 1855)
Ventral view of an adult tecnomorphic carapace, from the Tétreauville Formation, St. Lawrence Lowlands, sample S-2.

Fig. 7. *Ctenobolbina* sp.
Adult heteromorphic left valve, from the Nicolet Formation, St. Lawrence Lowlands, Carter Collection (S-13).

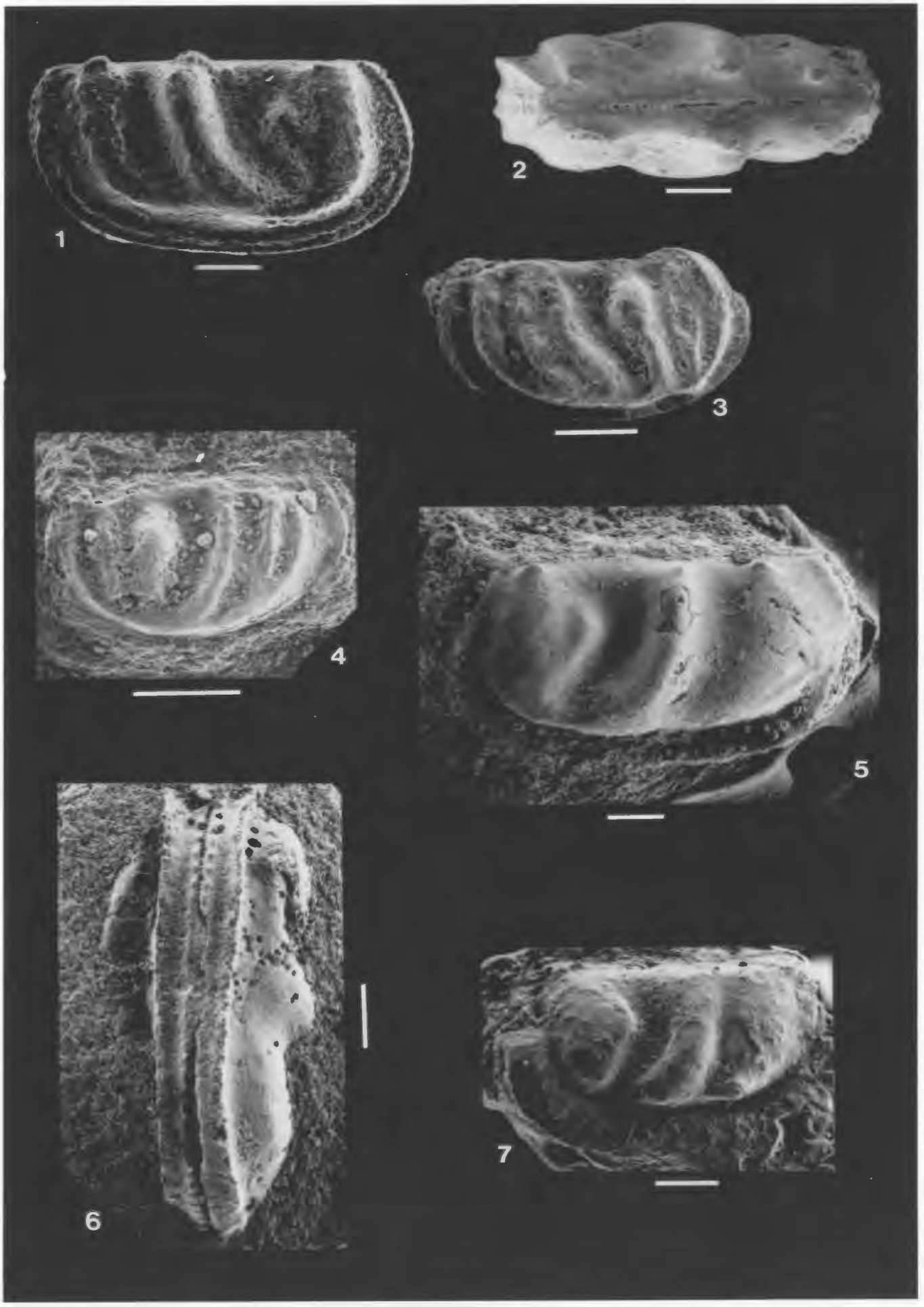
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PLATE 11

[all scale bars are 300 μ]

Fig. 1. *Ceratopsis chambersi* (Miller 1874)
Adult left valve, from the Deschambault Formation, St. Lawrence Lowlands, sample S-4.

Fig. 2. *Ceratopsis chambersi* (Miller 1874)
Adult right valve, from the Deschambault Formation, St. Lawrence Lowlands, sample S-4.

Fig. 3. *Ceratopsis chambersi* (Miller 1874)
Left valve with spine broken, from the Neuville Formation, St. Lawrence Lowlands, Carter Collection (S-19).

Fig. 4. *Ceratopsis chambersi* (Miller 1874)
Right-lateral view of an adult carapace, from the Deschambault Formation, St. Lawrence Lowlands, Carter Collection (S-18).

Fig. 5. *Ceratopsis* sp.
Left-lateral view of an adult carapace, from the Vauréal Formation, Anticosti Island, sample A-2.

Fig. 6. *Ceratopsis* sp.
Left-oblique view of an adult carapace, from the Vauréal Formation, Anticosti Island, sample A-2.

Fig. 7. *Ceratopsis* sp.
Right-lateral view of a juvenile carapace, from the Vauréal Formation, Anticosti Island, sample A-2.

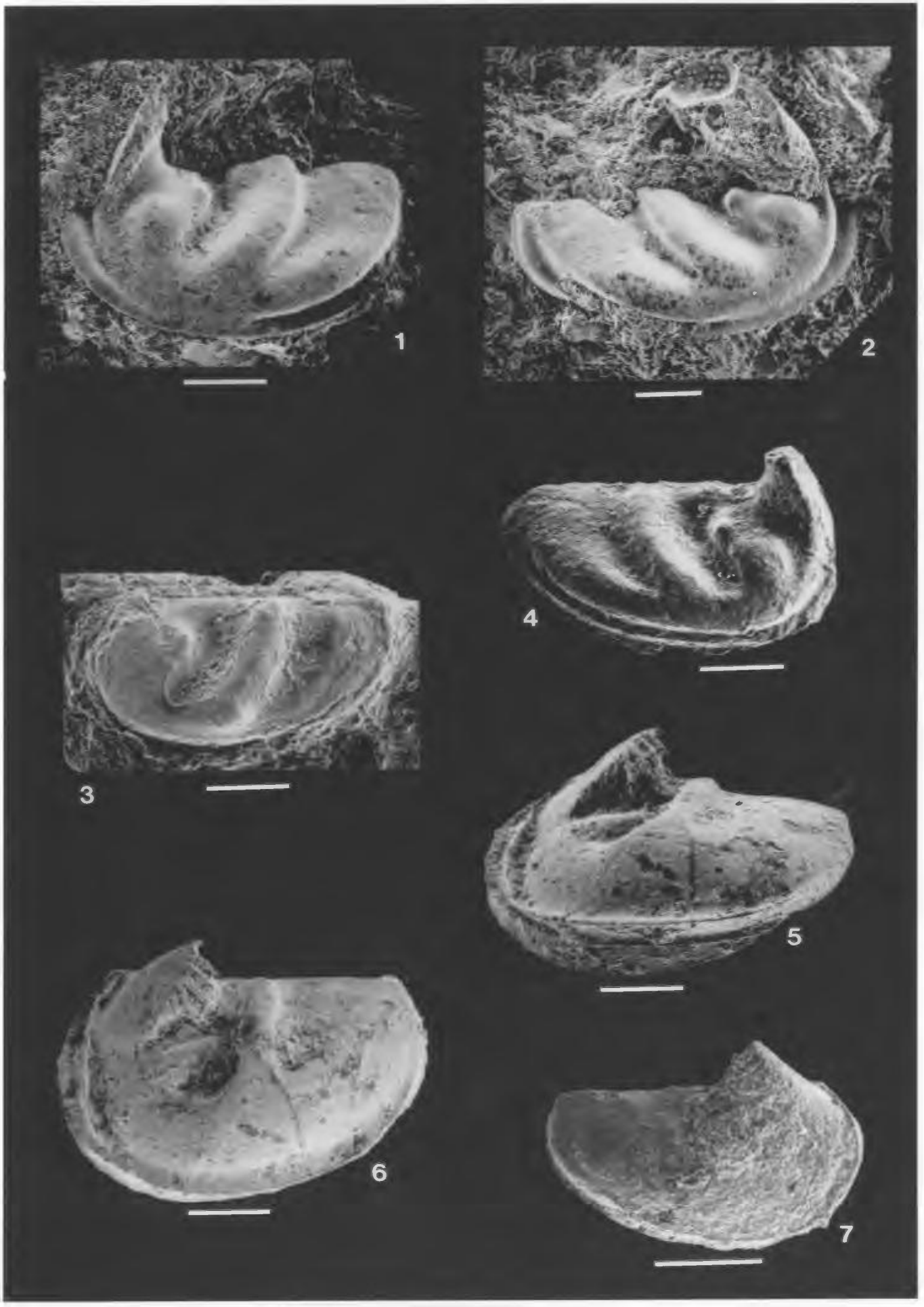
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PLATE 12

[all scale bars are 300 μ]

Fig. 1. *Lambeodella?* sp.
Left-lateral view of an adult carapace, from the Vauréal Formation, Anticosti Island, sample A-6.

Fig. 2. *Dicranella?* sp.
Left valve, from the Leray Formation, St. Lawrence Lowlands, Carter Collection (S-20).

Fig. 3. *Aechmina maccormicki* Copeland 1973
Fig. 4. Left valve, from Member 1, Ellis Bay Formation, Anticosti Island, sample A-1.

Fig. 5. *Aechmina maccormicki* Copeland 1973
Right valve, from Member 1, Ellis Bay Formation, Anticosti Island, sample A-1.

Fig. 6. *Bollia subaequata* Ulrich 1894
Right valve, from the Deschambault Formation, St. Lawrence Lowlands, Carter Collection (S-15).

Fig. 7. *Jonesites semilunatus* (Jones 1890)
Right valve, from Member 1, Ellis Bay Formation, Anticosti Island, sample A-7.

Fig. 8. *Jonesites semilunatus* (Jones 1890)
Right valve, from Member 1, Ellis Bay Formation, Anticosti Island, sample A-7.

Fig. 9. *Quasibollia persulcata* (Ulrich 1879)
Right valve, from the Utica Group, St. Lawrence Lowlands, Carter Collection (S-14).

Fig. 10. *Warthinia nodosa* (Ulrich 1890)
Left valve, from the Vauréal Formation, Anticosti Island, sample A-5.

Fig. 11. *Warthinia nodosa* (Ulrich 1890)
Right valve, from the Vauréal Formation, Anticosti Island, sample A-1.

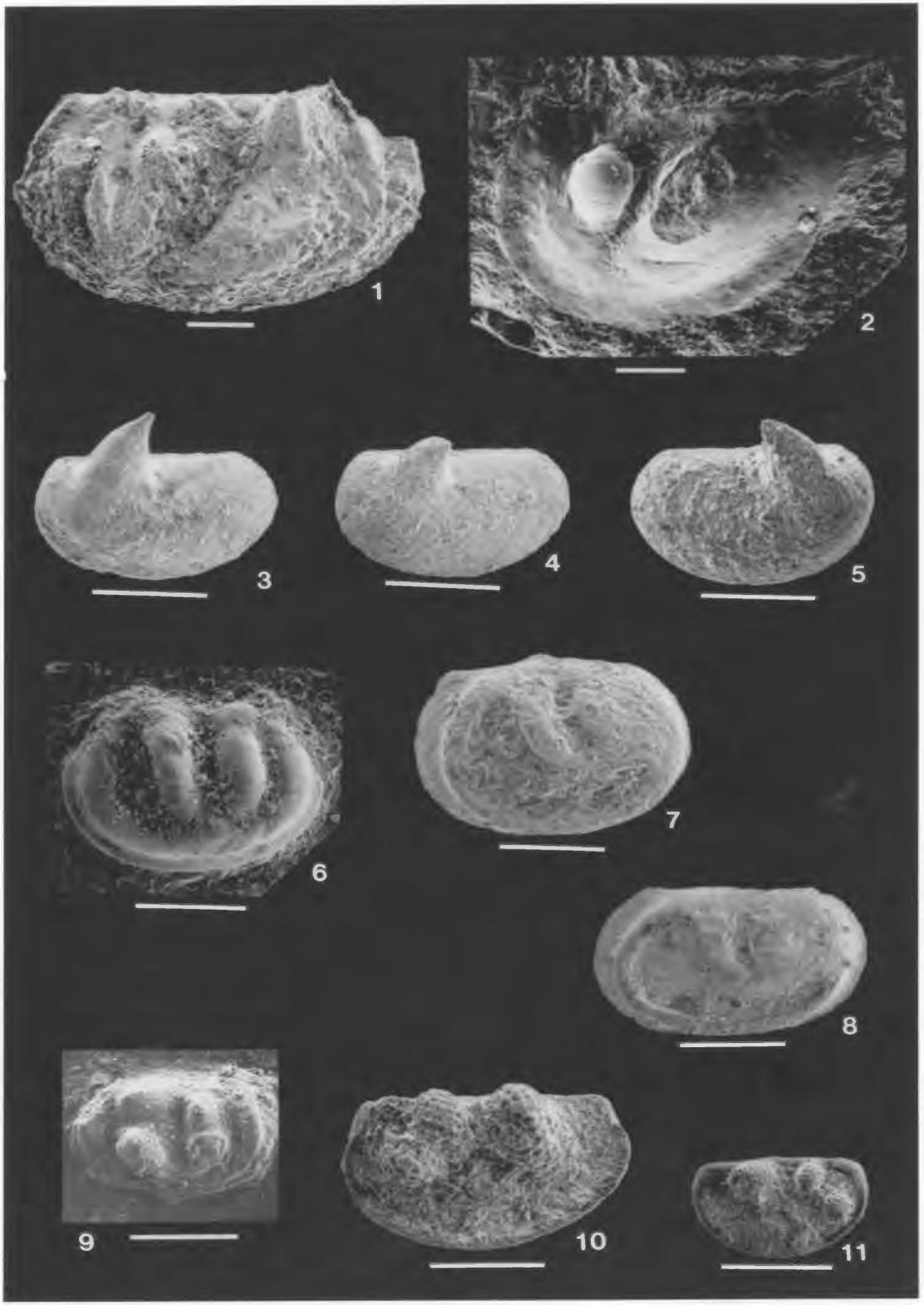
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PLATE 13

[all scale bars are 300 μ]

Fig. 1. *Jonesella obscura?*
Left valve, from the upper Trenton Group, St. Lawrence Lowlands, Carter Collection (S-22A).

Fig. 2. *Jonesella* sp.
Right valve, from the Nicolet Formation, St. Lawrence Lowlands, Carter Collection (S-24).

Fig. 3. *Aparchites fimbriatus* (Ulrich 1892)
Right-lateral view of an adult carapace, from the Beach Point Member, Lourdes Formation, western Newfoundland, sample (L-8).

Fig. 4. *Aparchites fimbriatus* (Ulrich 1892)
Ventral view of an adult carapace, from the Beach Point Member, Lourdes Formation, western Newfoundland, sample (L-8).

Fig. 5. *Aparchites fimbriatus* (Ulrich 1892)
Left-lateral view of a carapace, from the Beach Point Member, Lourdes Formation, western Newfoundland, sample (L-8).

Fig. 6. *Aparchites fimbriatus* (Ulrich 1892)
Left-lateral view of an adult carapace, from the Montréal Formation, St. Lawrence Lowlands, Carter Collection (S-6).

Fig. 7. *Aparchites* sp.
Left-lateral view of a carapace, from the Table Point Formation, western Newfoundland, samples T-4 and T-5.

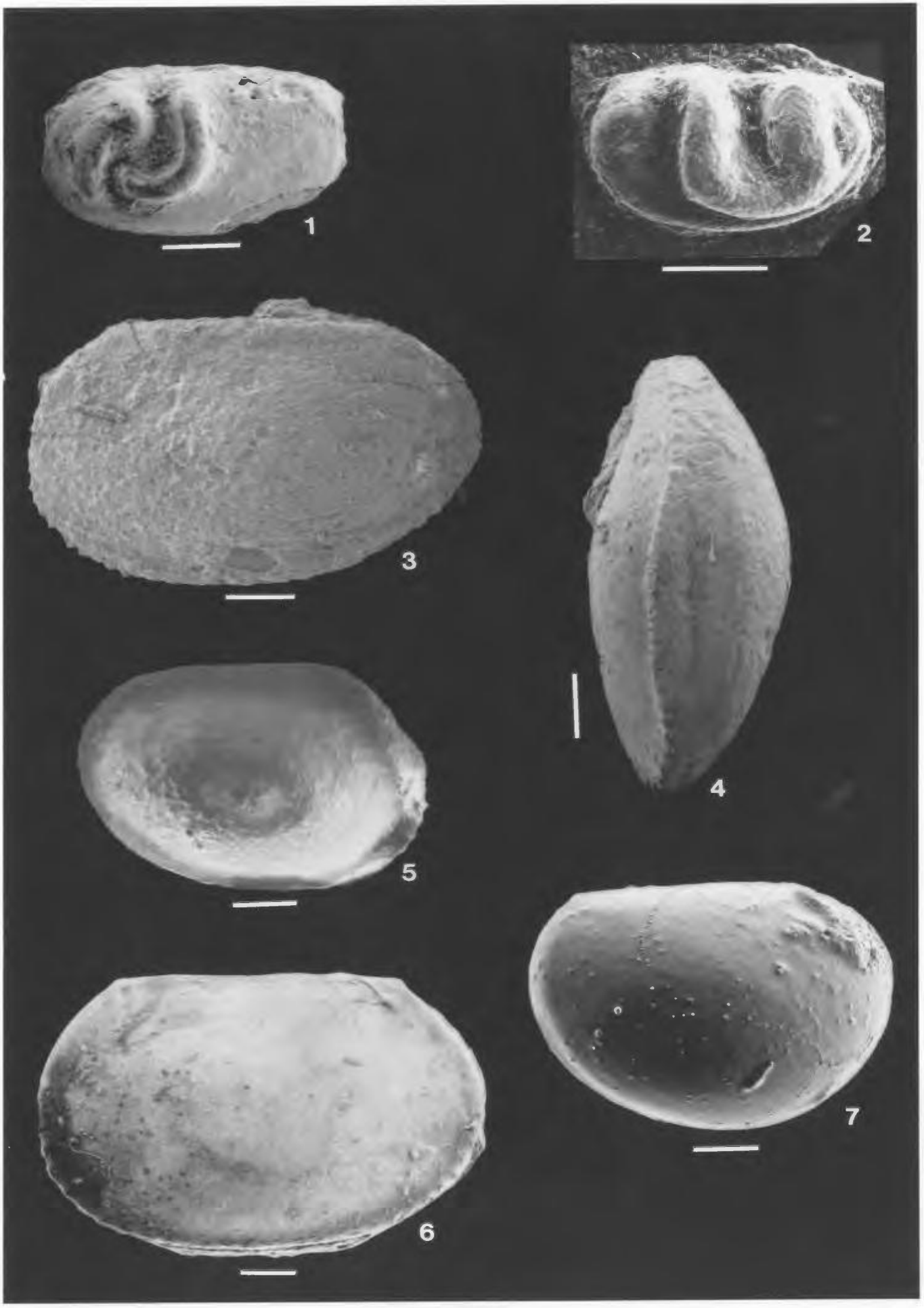
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PLATE 14

[all scale bars are 300 μ]

Fig. 1. *Saccelatia arrecta* (Ulrich 1894)
Right valve, from the Beach Point Member, Lourdes Formation, western Newfoundland, sample L-8.

Fig. 2. *Schmidtella sublenticularis* (Jones 1890)
Left-lateral view of an adult carapace, from Member 5, Ellis Bay Formation, Anticosti Island, sample A-16.

Fig. 3. *Schmidtella* sp.
Left-lateral view of an adult carapace, from the Beach Point Member, Lourdes Formation, western Newfoundland, sample L-10.

Fig. 4. *Schmidtella* sp.
A juvenile carapace, from the Beach Point Member, Lourdes Formation, western Newfoundland, sample L-9.

Fig. 5. *Leperditella rex* (Coryell and Schenck 1941)
Left-lateral view of an adult carapace, from the Table Point Formation, western Newfoundland, samples T-4 and T-5.

Fig. 6. *Leperditella rex* (Coryell and Schenck 1941)
Adult right valve, from the Table Point Formation, western Newfoundland, sample T-3.

Fig. 7. *Leperditella* sp. 1
Adult right valve, from the Deschambault Formation, St. Lawrence Lowlands, Carter Collection (S-11).

Fig. 8. *Leperditella* sp. 2
Valve, from the Fontaine Formation, St. Lawrence Lowlands, sample (S-5).

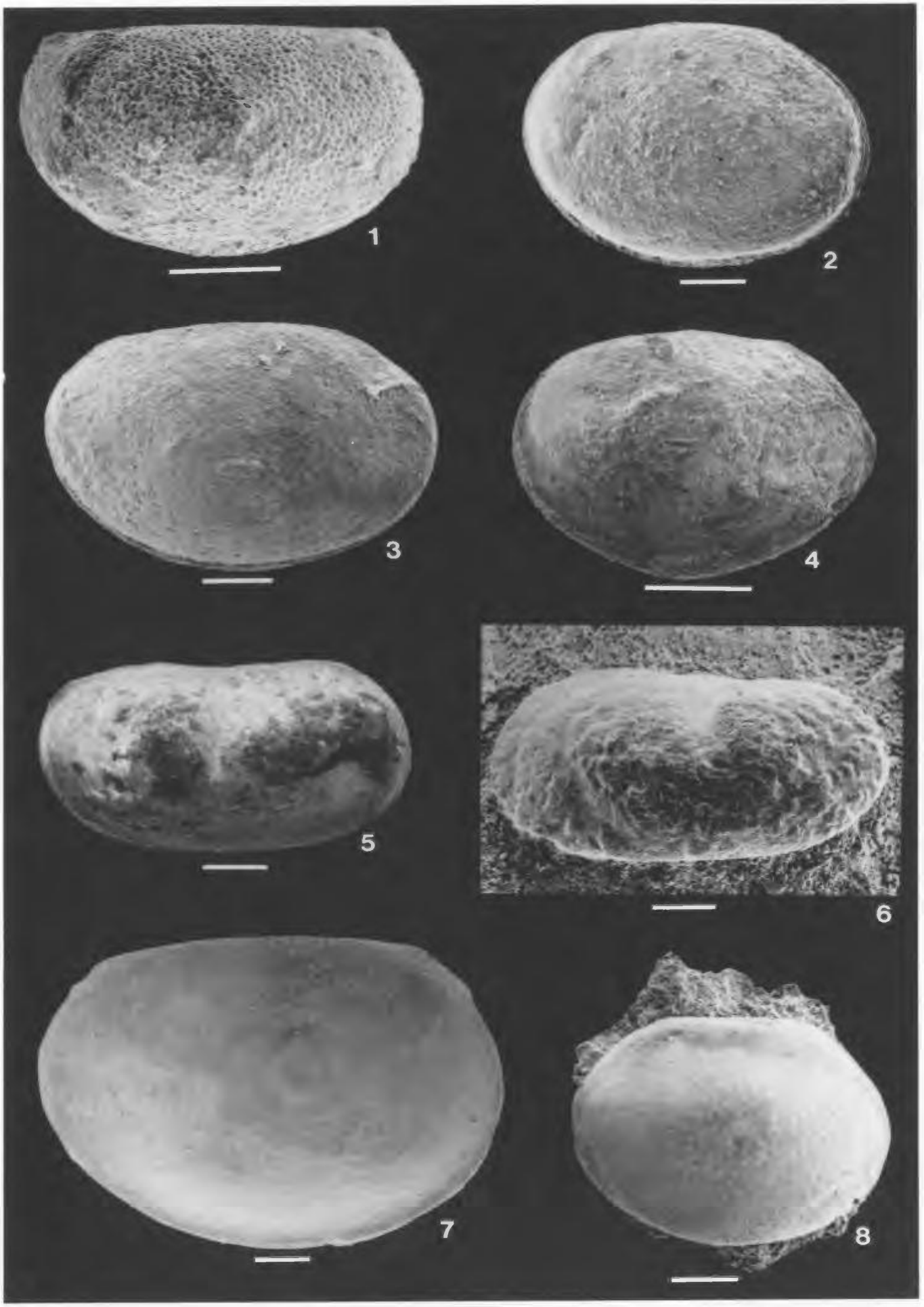
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PLATE 15

[all scale bars are 300 μ]

Fig. 1. *Ectoprimitia?* sp.
Right valve, from the Beach Point Member, Lourdes Formation, western Newfoundland, sample L-9.

Fig. 2. *Hallatia particylindrica* Kay 1934
Left valve, from the Deschambault Formation, St. Lawrence Lowlands, Carter Collection (S-18).

Fig. 3. *Hallatia canadensis* (Bassler 1928)
Left valve, from Member 5, Ellis Bay Formation, Anticosti Island, sample A-16.

Fig. 4. *Hallatia canadensis* (Bassler 1928)
Right valve, from Member 5, Ellis Bay Formation, Anticosti Island, sample A-16.

Fig. 5. *Eocytherella?* sp.
Right valve, from the Beach Point Member, Lourdes Formation, western Newfoundland, sample L-9.

Fig. 7. *Eridoconcha rugosa* Ulrich and Bassler 1923
Valve, from the Beach Point Member, Lourdes Formation, western Newfoundland, sample L-9.

Fig. 8. *Eridoconcha rugosa* Ulrich and Bassler 1923
Valve, from the Black Duck Member, Lourdes Formation, western Newfoundland, sample L-4.

Fig. 9. *Cryptophyllus oboloides* (Ulrich and Bassler 1923)
Valve, from Member 4, Ellis Bay Formation, Anticosti Island, sample A-15.

Fig. 10. *Cryptophyllus* sp. aff. *C. oboloides* (Ulrich and Bassler 1923)
Valve, from the Deschambault Formation, St. Lawrence Lowlands, sample S-4.

Fig. 11. *Cryptophyllus* sp. aff. *C. oboloides* (Ulrich and Bassler 1923)
Valve, from the Deschambault Formation, St. Lawrence Lowlands, Carter Collection (S-18).

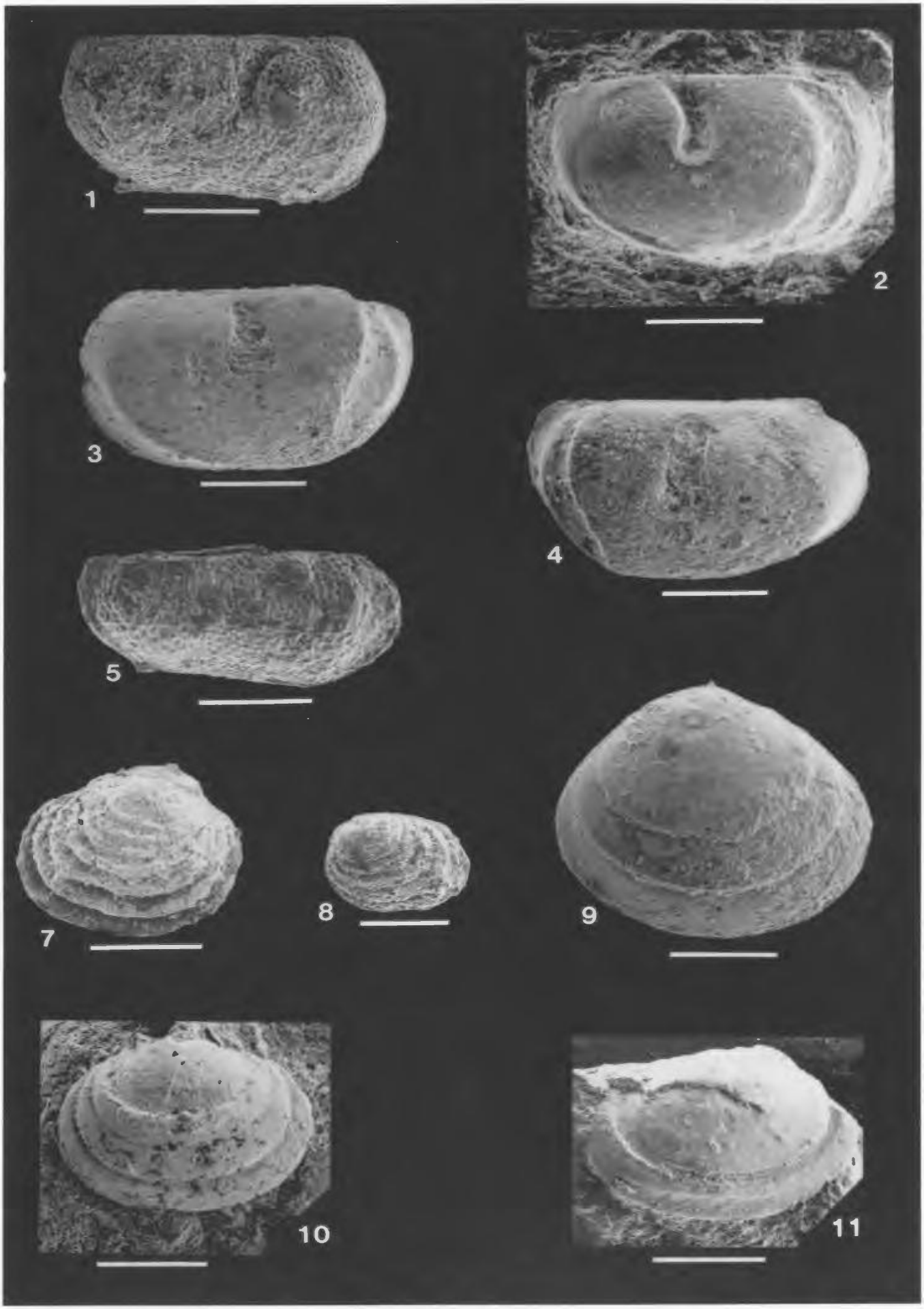
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PLATE 16

[all scale bars are 300 μ]

Fig. 1. *Phelobythocypris cylindrica* (Hall 1871)
Left-lateral view of a carapace, from Member 4, Ellis Bay Formation, Anticosti Island, sample A-14.

Fig. 2. *Phelobythocypris cylindrica* (Hall 1871)
Right-lateral view of a carapace, from Member 5, Ellis Bay Formation, Anticosti Island, sample A-16.

Fig. 3. *Krausella arcuata* Ulrich 1894
Left-lateral view of an adult carapace, from the Leray Formation, St. Lawrence Lowlands, Carter Collection (S-20).

Fig. 4. *Tubulibairdia jolieti* Copeland 1973
Right-lateral view of a carapace, from Member 4, Ellis Bay Formation, Anticosti Island, sample A-15.

Fig. 5. *Tubulibairdia jolieti* Copeland 1973
Right valve, from Member 5, Ellis Bay Formation, Anticosti Island, sample A-16.

Fig. 6. *Tubulibairdia jolieti* Copeland 1973
Ventral view of a carapace, from Member 1, Ellis Bay Formation, Anticosti Island, sample A-9.

Fig. 7. *Eograptiodactylus hyatti* Copeland 1973
Right valve, from Member 4, Ellis Bay Formation, Anticosti Island, sample A-15.

Fig. 8. *Balticella deckeri* (Harris 1931)
Right-lateral view of a carapace, from the Beach Point Member, Lourdes Formation, Newfoundland, sample L-8.

Fig. 9. *Balticeila deckeri* (Harris 1931)
Dorsal view of a carapace, from the Beach Point Member, Lourdes Formation, western Newfoundland, sample L-8.

Fig. 10. *Steusloffina ulrichi* Teichert 1937
Right-lateral view of a carapace, from the Deschambault Formation, St. Lawrence Lowlands, Carter Collection (S-18).

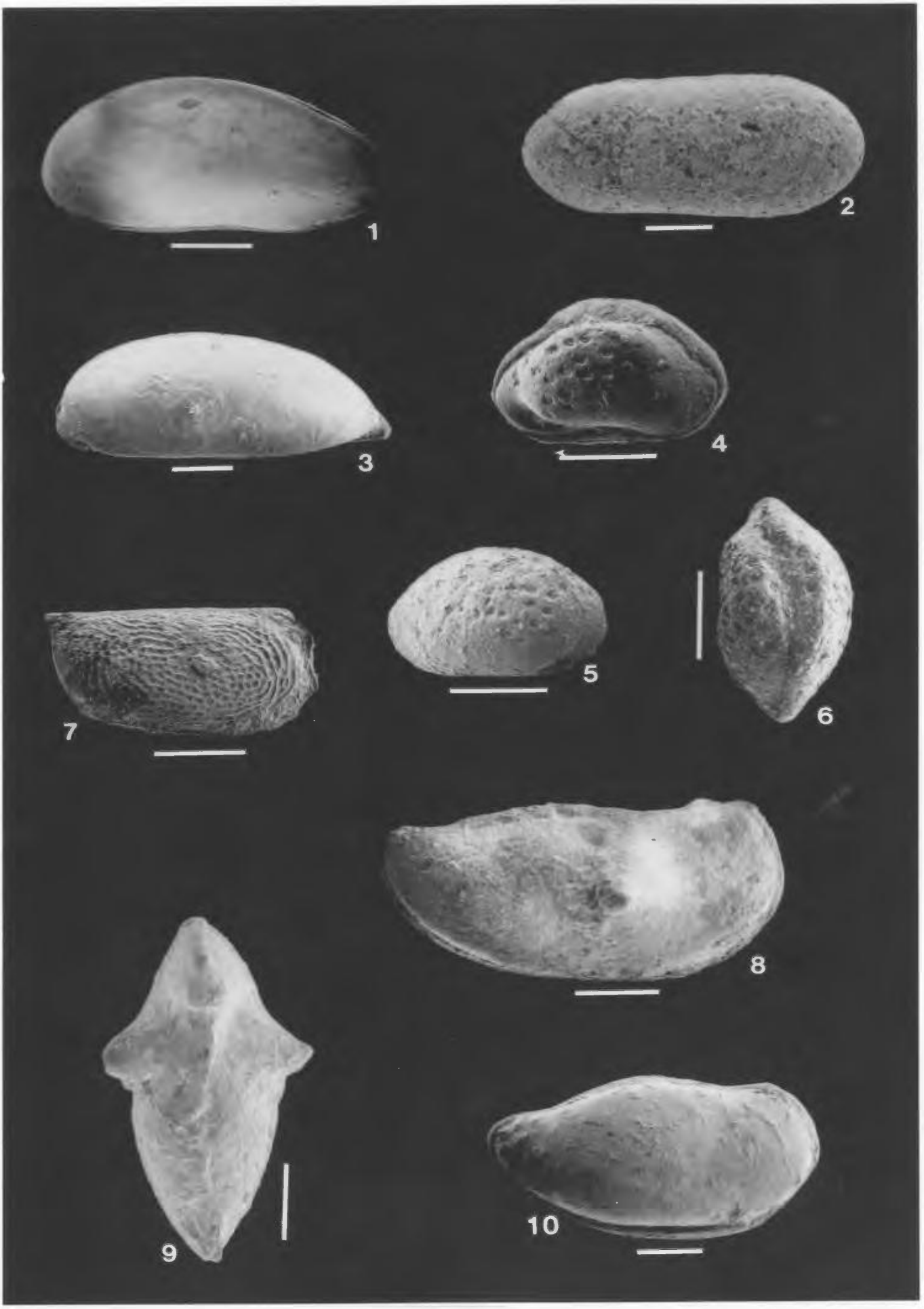
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PLATE 17

[staff is 1.5 m in length]

Fig. 1. View of the north side of Table Point, western Newfoundland.

Fig. 2. Massive and thick-bedded limestones of the Table Point Formation, Table Point; the cliff is about 23 m high.

Fig. 3. Thinly bedded limestones of the Shore Point Member, Lourdes Formation, east side of Long Point, western Newfoundland; the cliffs are about 25 m high.

Fig. 4. Shaly base of the Shore Point Member, Lourdes Formation, east side of Long Point; the top of the Black Duck Member is exposed in the foreground.

Fig. 5. Contact between sandy limestones of the Shore Point Member and the shaly base of the Black Duck Member, Lourdes Formation, east side of Long Point.


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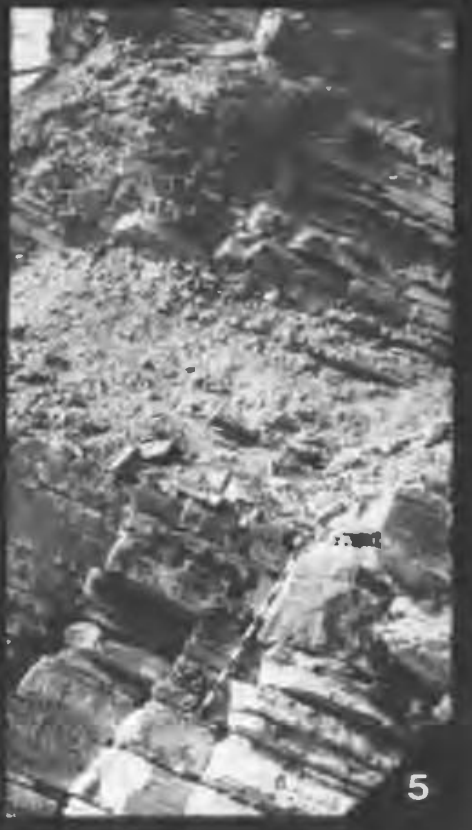
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PLATE 18

[staff is 1.5 m in length]

Fig. 1. Contact between the Lourdes Formation and the overlying Winterhouse Formation, tip of Long Point, western Newfoundland.

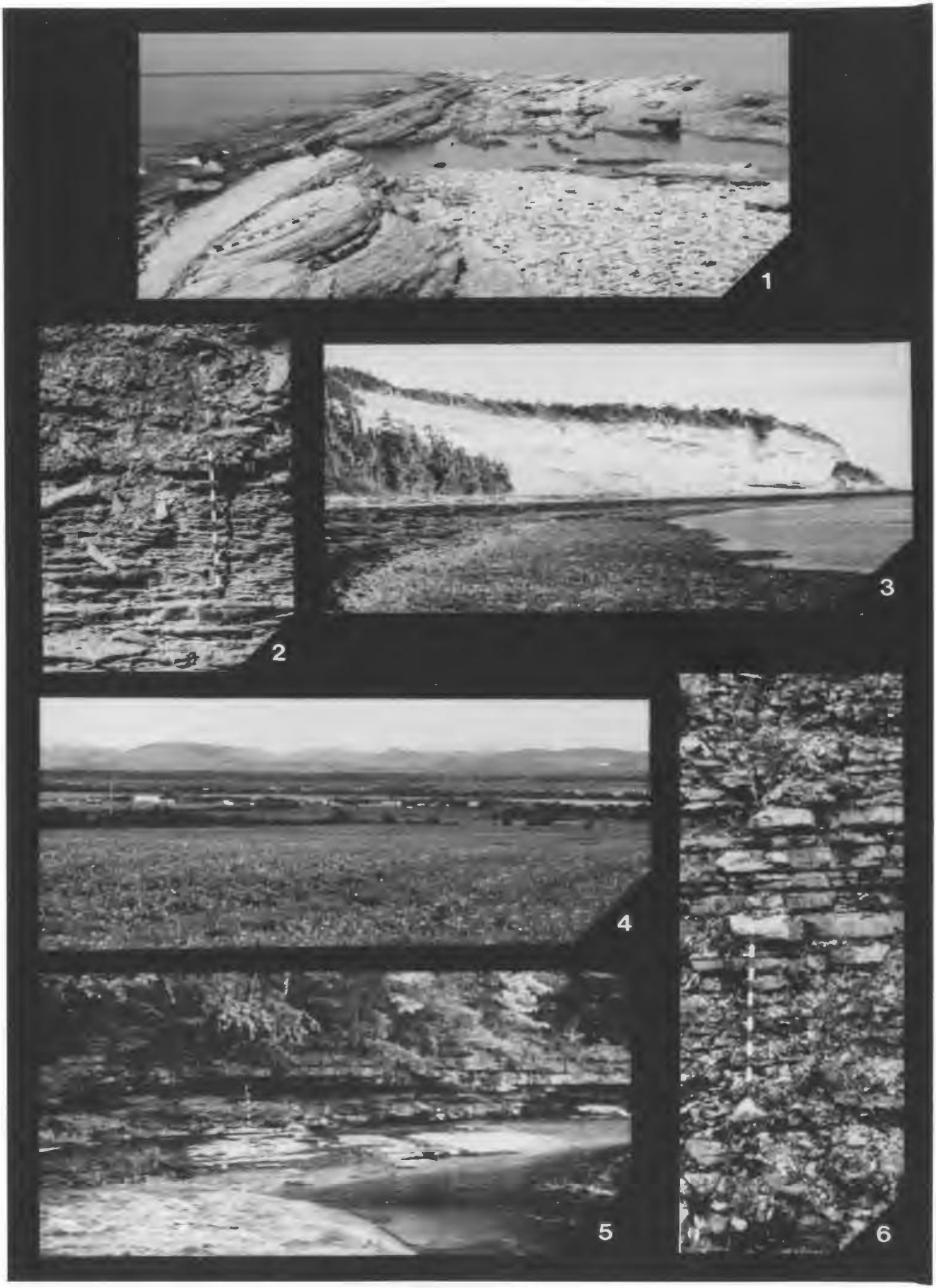
Fig. 2. Thinly bedded argillaceous limestones and sha - of the Vauréal Formation, Oil River, Anticosti Island.

Fig. 3. View of the Ellis Bay Formation, exposed in Junction Cliff, near Port Menier, Anticosti Island.

Fig. 4. View across the St. Lawrence Lowlands; note the St. Lawrence River and the Laurentian highlands.

Fig. 5. Boundary between the Ouareau Formation and the Deschambault Formation, exposed on the Ouareau River, St. Lawrence Lowlands.

Fig. 6. Interbedded argillaceous limestones and thin shales of the Montréal Formation, near Joliette, St. Lawrence Lowlands.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APPENDIX 1

List of samples, giving:

a) Brief geographical description of sampling locality and full grid reference.
b) Lithostratigraphical horizon sampled.
c) Sample lithology.
d) Ostracode preparation technique(s) used

Samples with a T- prefix, from Table Point, western Newfoundland.

T-1
a) Coastal cliffs about 0.5 km north-northeast of Table Point. (21UVF618793).
b) About 19 m above the base of the Table Point Formation.
c) Massive grey limestones - mainly lime mudstones and packstones.
d) Well preserved calcified ostracodes prepared using a vibra-tool; acid (HCl) preparation did not yield ostracodes.

T-2
a) Coastal cliffs about 0.4 km north-northeast of Table Point, (21UVF617791).
b) About 63 m above the base of the Table Point Formation.
c) Massive grey limestones - mainly burrowed wackestones.
d) Calcified ostracodes prepared using a vibra-tool; acid (HCl) preparation did not yield ostracodes.

T-3
a) Coastal cliffs about 0.3 km north-northeast of Table Point, (21UVF617789).
b) About 84 m above the base of the Table Point Formation.
c) Prominent chert bed overlain by recessed lime grainstones and mudstones; fallen blocks contain large numbers of well preserved leperditiid ostracodes.
d) Calcified ostracodes prepared using fine-needles and/or vibra-tool; acid preparation of limestones (HCl) and cherts (HF) did not yield ostracodes.

T-4
T-5
a) Cliff top barrens near Table Point, (21UVF618788).
b) Between 120 m and 150 m above the base of the Table Point Formation.
c) Well weathered limestone material in gullies and small strike-parallel outcrops of ostracode-rich lime grainstones.
d) Ostracodes washed from weathered material; calcified ostracodes in

unweathered material prepared using fine-needles and/or vibra-tool; acid (HCl) preparation did not yield ostracodes.

T-6
a) Coastal cliffs about 0.2 km north-northeast of Table Point, (21UVF617788).
b) About 155 m above the base of the Table Point Formation.
c) Well bedded grey limestones.
d) Calcified ostracodes prepared using fine-needles and/or vibra-tool; acid (HCl) preparation did not yield ostracodes.

T-7
a) Coastal cliffs about 0.1 km north-northeast of Table Point, (21UVF617788).
b) About 175 m above the base of the Table Point Formation.
c) Prominent chert bed overlain by recessed grey limestones and covered with broken limestone scree.
d) Calcified ostracodes from limestones prepared using vibra-tool; acid preparation of limestones (HCl) and cherts (HF) did not yield ostracodes.

T-8
a) Coastal cliffs about 0.1 km south-southwest of Table Point, (21UVF617786).
b) About 190 m above the base of the Table Point Formation.
c) Massive grey pseudoconglomeratic limestones.
d) Acid (HCl) preparation did not yield ostracodes.

T-9
a) Coastal cliffs about 0.1 km south-southwest of Table Point, (21UVF617786).
b) About 195 m above the base of the Table Point Formation.
c) Grey, well bedded fossiliferous limestones.
d) Calcified ostracodes prepared using fine-needles and/or vibra-tool; acid (HCl) preparation did not yield ostracodes.

T-10
a) Table Cove, about 0.9 km south-southwest of Table Point, (21UVF618778).
b) About 80 m above the base of the Table Cove Formation.
c) Interbedded ribbon limestones and black calcareous shales.
d) Calcified ostracodes prepared using fine-needles and/or vibra-tool; acid (HCl) preparation did not yield ostracodes.

T-11
a) Table Cove, about 1.0 km south-southwest of Table Point, (21UVF619777).
b) About 88 m above the base of the Table Cove Formation.
c) Ribbon limestones interbedded with black calcareous shales; shaly interbeds contain abundant trilobite fragments.

d) Calcified ostracodes prepared using fine-needles and/or vibra-tool; acid (HCl) preparation did not yield ostracodes.

Samples with an L- prefix, from Long Point, western Newfoundland.

L-1
a) Shore Point, about 6 km southwest of Black Duck Brook, (21UUD564911).
b) Lourdes Formation, about 8 m above the base of the Shore Point Member.
c) Shaly limestone.
d) Acid (HCl and HF) and vibra-tool preparation - no ostracodes recovered.

L-2
a) Shore Point, about 5.5 km southwest of Black Duck Brook, (21UUD567915).
b) Lourdes Formation, about 1 m above the base of the Black Duck Member.
c) Weathered blue-grey calcareous shale with lenses of nodular limestone.
d) Ostracodes washed from shales.

L-3
a) Shore Point, about 5 km southwest of Black Duck Brook, (21UUD571918).
b) Lourdes Formation, about 8 m above the base of the Black Duck Member.
c) Arenaceous limestone.
d) Acid (HCl and HF) and vibra-tool preparation - no ostracodes recovered.

L-4
a) Shore Point, about 4 km southwest of Black Duck Brook, (21UUD578927).
b) Lourdes Formation, about 2 m above the base of the Black Duck Member.
c) Blue-green weathering shales interbedded with minor knobbly limestones.
d) Ostracodes washed from shaly interbeds.

L-5
a) Shore Point, about 3 km southwest of Black Duck Brook, (21UUD584934).
b) Lourdes Formation, about 13 m above the base of the Black Duck Member.
c) Rubbly limestone.
d) Acid (HCl and HF) and vibra-tool preparation - no ostracodes recovered.

L-6
a) Shore Point, about 1 km southwest of Black Duck Brook, (21UUD599949).

b) Lourdes Formation, about 15 m above the base of the Black Duck Member.
c) Massive grey fossiliferous limestone.
d) Acid (HCl) and vibra-tool preparation - no ostracodes recovered.

L-7
a) East coast of Long Point at Black Duck Brook. (21UUD605956).
b) Lourdes Formation, top 6 m of the Black Duck Member.
c) Samples of fossiliferous limestone with visible leperditiids.
d) Ostracodes prepared with fine-needles.

L-8
a) East coast of Long Point, about 1 km northeast of Black Duck Brook, (21UUD612962).
b) Lourdes Formation, about 2 m above the base of the Beach Point Member.
c) Weathered blue-grey calcareous shale with minor nodular limestone interbeds.
d) Ostracodes washed from shales.

L-9
a) East coast of Long Point, about 4 km northeast of Black Duck Brook, (21UUD634983).
b) Lourdes Formation, about 6 m above the base of the Beach Point Member.
c) Browny-blue calcareous shales interbedded with thin grey knobbly limestones.
d) Ostracodes washed from shaly interbeds.

L-10
a) East coast of Long Point, about 6 km northeast of Black Duck Brook, (21UUD649998).
b) Lourdes Formation, about 3 m above the base of the Beach Point Member.
c) Brown weathering, blue-grey calcareous shales with interbeds of nodular limestone.
d) Ostracodes washed from shaly interbeds.

L-11
a) East coast of Long Point, about 6 km northeast of Black Duck Brook, (21UUD649998).
b) Lourdes Formation, about 5 m above the base of the Beach Point Member.
c) Brown weathering, blue-grey calcareous shales interbedded with thin grey knobbly limestones.
d) Ostracodes washed from shaly interbeds.

L-12
a) Beach Point, about 11 km northeast of Black Duck Brook,

(21UUE689032).

b) Lourdes Formation, about 17 m above the base of the Beach Point Member.

c) Light grey, thin-bedded knobbly limestone.

d) Acid (HCl) and vibra-tool preparation - no ostracodes recovered.

L-13

a) Beach Point, about 12 km northeast of Black Duck Brook, (21UUE696041).

b) Lourdes Formation, about 26 m above the base of the Beach Point Member.

c) Light grey arenaceous limestone.

d) Acid (HCl and HF) and vibra-tool preparation - no ostracodes recovered.

L-14

a) Beach Point, about 13 km northeast of Black Duck Brook, (21UUE701049).

b) Lourdes Formation, about 30 m above the base of the Beach Point Member.

c) Light grey crossbedded calcarenite.

d) Acid (HCl and HF) and vibra-tool preparation - no ostracodes recovered.

L-15

a) West coast of Long Point, about 11.5 km northeast of Black Duck Brook, (21UUE691038).

b) About 5 m above the base of the Winterhouse Formation.

c) Thin-bedded, dark grey calcareous siltstone interbedded with ripple-marked, lenticular beds of fine-grained sandstone; some weathered brachiopod coquinas

d) Washing and vibra-tool preparation - no ostracodes recovered.

L-16

a) West coast of Long Point, about 11 km northeast of Black Duck Brook, (21UUE687035).

b) About 25 m above the base of the Winterhouse Formation.

c) Thin-bedded, blue-grey siltstone interbedded with lenticular, ripple-marked beds of fine-grained calcareous sandstone.

d) Acid (HCl and HF) and vibra-tool preparation - no ostracodes recovered.

L-17

a) West coast of Long Point, about 10.5 km northeast of Black Duck Brook, (21UUE681030).

b) About 54 m above the base of the Winterhouse Formation.

c) Prominent nodular bed of medium-grained calcareous sandstone.

d) Acid (HCl) and vibra-tool preparation - no ostracodes recovered.

L-18

a) West coast of Long Point, about 10 km northeast of Black Duck Brook, (21UUE676025).

b) About 57 m above the base of the Winterhouse Formation.
c) Dark grey, calcareous siltstone interbedded with thin beds of fine-grained sandstone.
d) Acid (HCl and HF) and vibra-tool preparation - no ostracodes recovered.

L-19 a) West coast of Long Point, about 9 km northeast of Black Duck Brook, (21UUE666018).
b) About 71 m above the base of the Winterhouse Formation.
c) Weathered fissile siltstone.
d) Washing and acid (HCL and HF) preparation - no ostracodes recovered.

L-20 a) West coast of Long Point, about 8.5 km northeast of Black Duck Brook, (21UUE662013).
b) About 75 m above the base of the Winterhouse Formation.
c) Dark grey siltstone.
d) Acid (HCl and HF) and vibra-tool preparation - no ostracodes recovered.

L-21 a) West coast of Long Point, about 3 km northeast of Black Duck Brook, (21UUD626978).
b) About 88 m above the base of the Winterhouse Formation.
c) Grey, fine to medium-grained sandstone interbedded with dark grey weathered siltstone; some brachiopod coquinas.
d) Washing and vibra-tool preparation - no ostracodes recovered.

L-22 a) West coast of Long Point, about 2 km northeast of Black Duck Brook, (21UUD617972).
b) About 122 m above the base of the Winterhouse Formation.
c) Light grey, fine to medium-grained calcareous sandstone.
d) Acid (HCl and HF) and vibra-tool preparation - no ostracodes recovered.

L-23 a) West coast of Long Point, about 0.8 km northeast of Black Duck Brook, (21UUD609964).
b) About 232 m above the base of the Winterhouse Formation.
c) Light grey, fine to medium-grained calcareous sandstone interbedded with dark grey siltstone.
d) Acid (HCl and HF) and vibra-tool preparation - no ostracodes recovered.

L-24 a) West coast of Long Point, about 0.5 km northeast of Black Duck Brook, (21UUD605963).
b) About 278 m above the base of the Winterhouse Formation.
c) Grey, ripple-marked, fine to medium-grained calcareous sandstone.
d) Acid (HCl and HF) and vibra-tool preparation - no ostracodes recovered.

L-25
a) West coast of Long Point, about 0.3 km northeast of Black Duck Brook, (21UUD603961).
b) About 318 m above the base of the Winterhouse Formation.
c) Grey-green, medium-grained sandstone.
d) Acid (HCl) and vibra-tool preparation - no ostracodes recovered.

L-26
a) Stream on north side of Lourdes Cove, (21UUD527908).
b) Upper part of the Winterhouse Formation.
c) Mauvy-grey, fine-grained micaceous sandstone interbedded with dark grey weathered siltstone.
d) Washing and acid (HCl and HF) preparation - no ostracodes recovered.

L-27
a) Stream on north side of Lourdes Cove, (21UUD528908).
b) Upper part of the Winterhouse Formation.
c) Greeny-grey, medium-grained sandstone with minor siltstone interbeds.
d) Washing and acid (HCl and HF) preparation - no ostracodes recovered.

L-28
a) Low cliffs on the east side of Lourdes Cove, (21UUD519906).
b) Upper part of the ?Winterhouse Formation.
c) Greeny-grey, weathered sandy siltstone with thin lenses of small brachiopods.
d) Weathered material washed - no ostracodes recovered.

L-29
a) About 1 km east of Three Rock Point, (21UUD459879).
b) Lourdes Formation, about 15 m above the base of the Beach Point Member.
c) Grey, thin-bedded knobbly limestones interbedded with blue-grey calcareous shales.
d) Shaly interbeds washed - no ostracodes recovered.

L-30
a) About 0.3 km east of Three Rock Point, (21UUD451878).
b) Lourdes Formation, about 3 m above the base of the Beach Point Member.
c) Grey, thin-bedded knobbly limestones interbedded with blue-grey calcareous shales.
d) Shaly interbeds washed - no ostracodes recovered.

Samples with an A- prefix, from Anticosti Island, Québec.

A-1
a) Oil River, about 0.7 km upstream of mouth, (20UML601205).
b) Vauréal Formation, about 26 m above base of Bolton's (1961) section.
c) Shaly limestone interbedded with grey shale.

d) Ostracodes washed from shaly interbeds.

A-2
a) Oil River, about 1.2 km upstream of mouth, (20UML596200).
b) Vauréal Formation, about 49 m above base of Bolton's (1961) section.
c) Grey shale interbedded with thin beds of limestone.
d) Ostracodes washed from shales.

A-3
a) Oil River, about 1.8 km upstream of mouth, (20UML596197).
b) Vauréal Formation, about 67 m above base of Bolton's (1961) section.
c) Grey shale interbedded with fine-grained nodular limestone.
d) Ostracodes washed from shales.

A-4
a) Oil River, about 0.1 km upstream of bridge, (20UML587164).
b) Vauréal Formation, about 130 m above base of Bolton's (1961) section.
c) Grey, weathered limestone with thin shale interbeds.
d) Ostracodes washed from shaly interbeds.

A-5
a) Oil River, about 3.3 km upstream of bridge, (20UML591134).
b) Vauréal Formation, about 210 m above base of Bolton's (1961) section.
c) Brown weathering, coralline limestone with thin shaly interbeds.
d) Ostracodes washed from shaly interbeds.

A-6
a) Oil River, about 4.7 km upstream of bridge, (20UML588119).
b) Vauréal Formation, about 250 m above base of Bolton's (1961) section.
c) Grey weathering, shaly limestone interbedded with blue-grey shales.
d) Ostracodes washed from shaly interbeds.

A-7
a) Oil River, about 7.1 km upstream of bridge, (20UML589100).
b) Ellis Bay Formation, Member 1, about 315 m above base of Bolton's (1961) section.
c) Fossiliferous green to blue-grey shale.
d) Ostracodes washed from shales.

A-8
a) Pointe à l'Épinette, (20UML991108).
b) Vauréal Formation, exposed in cliff section, (stratigraphically below Oil River section).
c) Grey weathered limestone interbedded with shale.
d) Ostracodes washed from shaly interbeds.

A-9
a) Junction Cliff, Anse aux Fraises, (20ULL962201).
b) Ellis Bay Formation, top of Member 1.
c) Fossiliferous green and grey shale interbedded with nodular limestone.
d) Ostracodes washed from shaly interbeds.

A-10
a) Junction Cliff, Anse aux Fraises, (20ULL964197).
b) Ellis Bay Formation, middle of Member 2.
c) Grey to grey-brown limestone with minor shale interbeds.
d) Ostracodes washed from shaly interbeds and weathered limestones.

A-11
a) Midway between Junction Cliff and Pointe Laframboise, (20ULL972187).
b) Ellis Bay Formation, middle of Member 3.
c) Interbedded grey-green shale and limestone.
d) Ostracodes washed from shaly interbeds.

A-12
a) Pointe Laframboise, (20ULL977178).
b) Ellis Bay Formation, base of Member 5.
c) Green shale with some shaly limestone interbeds.
d) Ostracodes washed from shales.

A-13
a) Falaise Ouest, (20ULL997186).
b) Ellis Bay Formation, middle of Member 2.
c) Grey weathered limestone with minor shale interbeds.
d) Ostracodes washed from shaly interbeds.

A-14
a) Cap Henri, (20UML003176).
b) Ellis Bay Formation, Member 4.
c) Weathered argillacecus limestones interbedded with grey shales.
d) Ostracodes washed from shaly interbeds.

A-15
a) Cap Blanc, (Port Menier Quarry), (20UML031184).
b) Ellis Bay Formation, Member 4.
c) Grey to grey-brown limestones with minor interbeds of grey shale.
d) Ostracodes washed from shaly interbeds and weathered limestones.

A-16
a) Les Roselets, (Anse aux Navets), (20UML043174).
b) Ellis Bay Formation, middle part of Member 5.
c) Grey-green shales interbedded with argillaceous limestones.
d) Ostracodes washed from shaly interbeds.

Samples with an S- prefix, from the St. Lawrence Lowlands of Québec.

S-1
a) Quarry about 3 km south-southwest of Kahnawake, Lachine map-area, (18TXF015262).
b) Middle of the Laval Formation, Chazy Group.
c) Crossbedded calcarenites interbeded with dark green shales.

d) Washing, acid and vibra-tool preparation - no ostracodes recovered.

S-2
a) Small outcrops in railway siding, Montréal North, Laval map-area, (18TXF098518).
b) Tétreauville Formation, Trenton Group.
c) Grey, thin-bedded argillaceous limestones with weathered shaly partings.
d) Calcified ostracodes prepared from weathered limestones using fine-needles; washing of weathered shales did not yield ostracodes.

S-3
a) Quarry about 1.5 km west-northwest of Saint-Jacques, Laurentides map-area, (18TXF093895).
b) Just above the base of the Deschambault Formation.
c) Weathered shaly limestone.
d) Weathered material washed - no ostracodes recovered.

S-4
a) River bank exposures about 0.3 km downstream of the Pont des Dalles, Ouareau River, Laurentides map-area, (18TXF153937).
b) About 6 m above the base of the Deschambault Formation; see Clark and Globensky (1976b, p. 62) for description of the section.
c) Grey, coarse-grained crystalline limestones interbedded with thinly bedded fine-grained limestones.
d) Well preserved calcified ostracodes prepared using a vibra-tool; acid (HCl) preparation did not yield ostracodes.

S-5
a) River bank exposures about 0.7 km downstream of the Radnor des Forges bridge, Lard River, Trois-Rivières map-area, (18TXG898513).
b) Just above the base of the Fontaine Formation; see Clark and Globensky (1976c, p. 21) for description of the section.
c) Thinly bedded, fine-grained crystalline limestones with a few thin shaly interbeds.
d) Well preserved calcified ostracodes prepared using a vibra-tool; acid (HCl) preparation did not yield ostracodes.

S-6
a) The old Labelle Union Rock Quarry, Saint-Michel district, Montréal North, Laval map-area, (18TXF0746); this was Carter's (1957) sampling locality #11, but is now infilled.
b) Base of the Montréal Formation, Trenton Group.
c) Grey, thinly bedded argillaceous limestones with numerous shale interbeds.
d) Carter (1957) prepared ostracodes from this locality with a vibra-tool; his collections are stored in the Redpath Museum, Montréal.

S-7
a) The old National Quarry, Saint-Michel district, Montréal North, Laval

map-area, (18TXF0847); this was Carter's (1957) sampling locality #9, but is now inaccessible.

b) Upper part of the Deschambault Formation.

c) Grey, fine to coarse-grained crystalline limestone.

d) Carter (1957) prepared ostracodes from this locality with a vibra-tool; his collections are stored in the Redpath Museum, Montréal.

S-8

a) Roadcut temporarily exposed during construction of Island Boulevard, Montréal North, Laval map-area, (18TXF1053); this was Carter's (1957) sampling locality #6, but is now inaccessible.

b) Tétreauville Formation, Trenton Group.

c) Lithology uncertain, but probably thinly bedded grey limestones.

d) Carter (1957) prepared ostracodes from this locality with a vibra-tool; his collections are stored in the Redpath Museum, Montréal.

S-9

a) Small poorly exposed hillside outcrops about 4 km west of Laurentides, Laurentides map-area, (18TWF934788); this was Carter's (1957) sampling locality #1.

b) Upper part of the Beauharnois Formation, Beekmantown Group.

c) Weathered grey dolomite.

d) Carter (1957) prepared ostracodes from this locality with a vibra-tool; his collections are stored in the Redpath Museum, Montréal.

S-10

a) Very poorly exposed river bank exposures, Chaloupe River about 3.8 km north of Saint-Thomas, Sorel map-area, (18TXG272015); this was Carter's (1957) sampling locality #25.

b) Upper part of the Deschambault Formation.

c) Irregularly bedded fine-grained limestone.

d) Carter (1957) prepared ostracodes from this locality with a vibra-tool; his collections are stored in the Redpath Museum, Montréal.

S-11

a) River bank exposures, east bank of Chicot River, about 0.6 km north of the Saint-Cuthbert bridge, Sorel map-area, (18TXG368132); this was Carter's (1957) sampling locality #20.

b) Lower part of the Deschambault Formation; see Clark and Globensky (1976a, p. 74) for description of the section.

c) Grey crystalline limestones.

d) Carter (1957) prepared ostracodes from this locality with a vibra-tool; his collections are stored in the Redpath Museum, Montréal.

S-12

a) Abandoned and now partially infilled quarry, about 3.2 km due west of Saint-Barthémy, Sorel map-area, (18TXG408165); this was Carter's (1957) sampling locality #19.

b) Tétreauville Formation, Trenton Group.
c) An alternating sequence of thicker bedded grey limestones and thinner bedded dark shales.
d) Carter (1957) prepared ostracodes from this locality with a vibra-tool; his collections are stored in the Redpath Museum, Montréal.

S-13 a) Section along the west bank of the Nicolet River, Saint-Léonard-d'Aston map-area, (18TXG945128); this was Carter's (1957) sampling locality #46.
b) Upper part of the St. Hilaire Member, Nicolet Formation; see Clark (1964a) and Walters *et al.* (1982) for description of the section.
c) Dark brown shales with some thin beds of sandstone and limestone.
d) Carter (1957) prepared ostracodes from this locality with a vibra-tool; his collections are stored in the Redpath Museum, Montréal.

S-14 a) Exposures on the east bank of the Saint-Maurice River opposite Les Vieilles-Forges, Trois-Rivières map-area, (18TXG804412); this was Carter's (1957) sampling locality #30.
b) Utica Group; see Clark and Globensky (1976c, p. 51) for description of the section.
c) Dark grey, massive and thinly bedded shales.
d) Carter (1957) prepared ostracodes from this locality with a vibra-tool; his collections are stored in the Redpath Museum, Montréal.

S-15 a) River bank exposures along the southeast bank of the Saint-Anne River, about 2 km southwest of the Saint-Alban bridge, Grondines map-area, (18TYG221758); access to this section is best achieved from the farm at (18TYG231752); this was Carter's (1957) sampling locality #36.
b) Saint-Casimir Member, Neuville Formation; see Clark and Globensky (1975, pp. 57-58) for description of this part of the Saint-Anne section.
c) Excellent exposures of fossiliferous browny-grey limestones.
d) Carter (1957) prepared ostracodes from this locality with a vibra-tool; his collections are stored in the Redpath Museum, Montréal.

S-16 a) River bank exposures along the northwest bank of the Saint-Anne River, about 1.2 km southwest of the Saint-Alban bridge, Grondines map-area, (18TYG228765); these exposures are best examined in the fall, when the river is at its lowest; this was Carter's (1957) sampling locality #33.
b) Upper part of the Deschambault Formation.
c) Light grey, coarsely crystalline limestone.
d) Carter (1957) prepared ostracodes from this locality with a vibra-tool; his collections are stored in the Redpath Museum, Montréal.

S-17

a) River bank exposures along the southeast bank of the Saint-Anne River, about 1 km southwest of the Saint-Alban bridge, Grondines map-area, (18TYG229765); this was Carter's (1957) sampling locality #34.

b) About 6 m below the top of the Deschambault Formation; see Clark and Globensky (1975, p. 57) for description of the section.

c) Light grey, coarsely crystalline limestone.

d) Carter (1957) prepared ostracodes from this locality with a vibra-tool; his collections are stored in the Redpath Museum, Montréal.

S-18

a) Exposures along the west bank of the Saint-Anne River between the Saint-Alban dam and the road bridge, Grondines map-area, (18TYG234769); these exposures are at the base of a steep gorge and can only be examined when the river is very low and water is not flowing over the dam; this was Carter's (1957) sampling locality #32.

b) The basal 2 m of the Deschambault Formation.

c) Alternating beds of lighter coarse-grained and darker fine-grained, fossiliferous limestones.

d) Carter (1957) prepared ostracodes from this locality with a vibra-tool; his collections are stored in the Redpath Museum, Montréal.

S-19

a) Small exposures along the side of a ditch about 0.6 km west of the Grondines wharf, Grondines map area, (18TYG263663); this was Carter's (1957) sampling locality #44.

b) About 2 m below the top of the Grondines Member, Neuville Format on; see Clark and Globensky (1975, p. 97) for description of the section.

c) Grey shaly limestone.

d) Carter (1957) prepared ostracodes from this locality with a vibra-tool; his collections are stored in the Redpath Museum, Montréal.

S-20

a) River bank and river bed exposures along the east side of the Jacques-Cartier River immediately north of Pont-Rouge, Saint-Raymond map-area, (19TBB938818); these exposures are only accessible at low water in the fall; this was Carter's (1957) sampling locality #48.

b) Black River Group; see Clark and Globensky (1973, pp. 14-19) for description of the section.

c) Dark thinly bedded limestones.

d) Carter (1957) prepared ostracodes from this locality with a vibra-tool; his collections are stored in the Redpath Museum, Montréal.

S-21

a) Exposures along the north shore of the Saint-Lawrence River immediately east of the Neuville wharf, Portneuf map-area, (19TCB033746); this was Carter's (1957) sampling locality #56.

b) Grondines Member, Neuville Formation; see Clark and Globensky

(1973, pp. 30-36) for description of the section.

c) Dark grey, semi-lithographic limestone with thin shale interbeds; fossils are confined to the upper surfaces of some of the limestone beds.

d) Carter (1957) prepared ostracodes from this locality with a vibra-tool; his collections are stored in the Redpath Museum, Montréal.

S-22

a) Core from a depth of 249 m (S-22A), 283-289 m (S-22B) and 387 m (S-22C) in the Oil Selections No. 32 drill hole, Verchères map-area, (18TXF256827); Carter (1957) termed this drill hole #H9.

b) Trenton Group (S-22A, S-22B) and Deschambault Formation (S-22C); see Clark and Globensky (1977, p. 60) for summary log of the borehole.

c) Interbedded shales and limestones (S-22A, S22B) and light grey crystalline limestone (S-22C).

d) Carter (1957) prepared ostracodes from this drill hole with a vibra-tool; his collections are stored in the Redpath Museum, Montréal.

S-23

a) Core from a depth of 103-109 m in the Lounan No. 1 drill hole, Verchères map-area, (18TXF354923); Carter (1957) termed this drill hole #H7.

b) Nicolet Formation; see Clark and Globensky (1977, p. 58) for summary log of the borehole.

c) Interbedded dark grey shales and siltstones.

d) Carter (1957) prepared ostracodes from this drill hole with a vibra-tool; his collections are stored in the Redpath Museum, Montréal.

S-24

a) Cuttings and core from a depth of 165-168 m in the Imperial Lowlands No. 2 drill hole, Trois-Rivières map-area, (18TXG883295); Carter (1957) termed this drill hole #H12.

b) Lower part of the Nicolet Formation; see Clark and Globensky (1976c, p. 82) for summary log of the borehole.

c) Thinly bedded dark grey shales and siltstones.

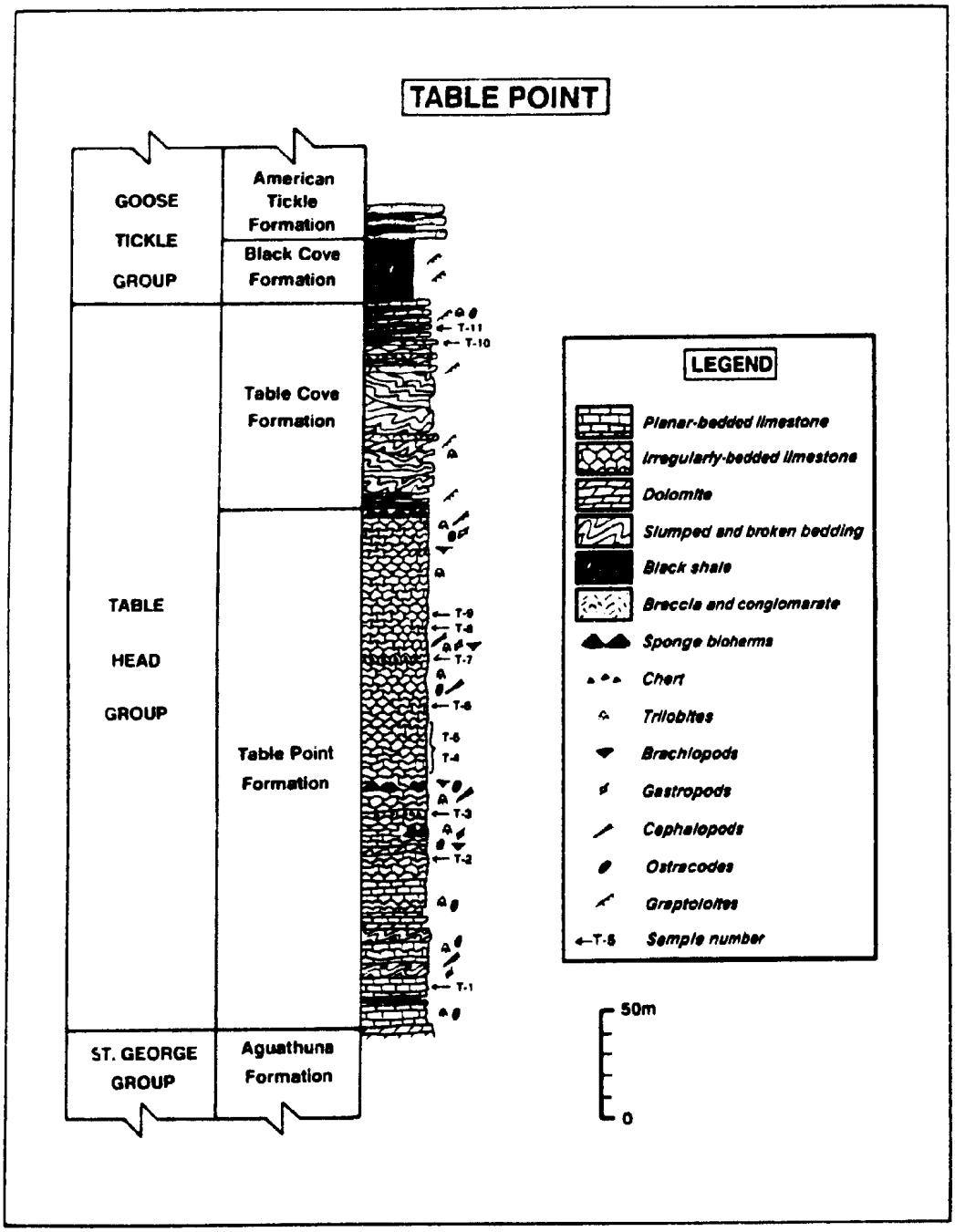
d) Carter (1957) prepared ostracodes from this drill hole with a vibra-tool; his collections are stored in the Redpath Museum, Montréal.

APPENDIX 2

List of 1:50000 maps used during this study.

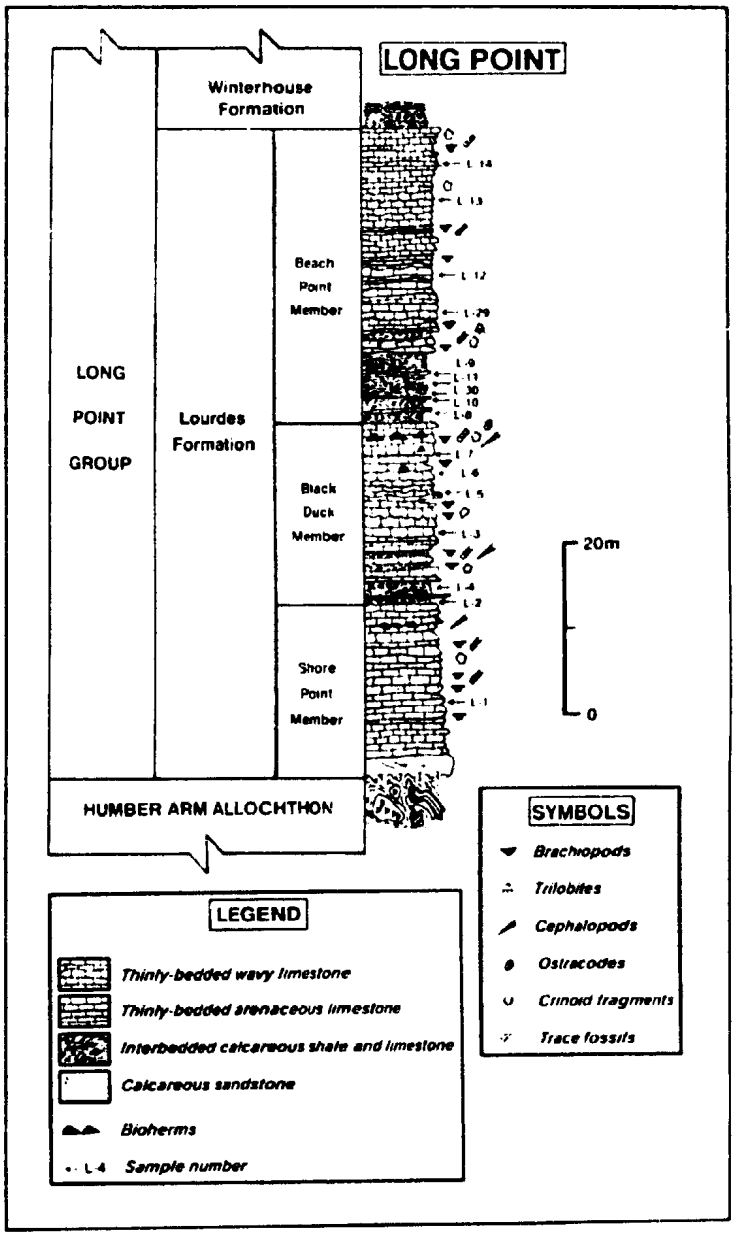
	Sheet No.	Year	Edition
Western Newfoundland			
Bellburns	12 I/5 & I/6	1973	2nd
Stephenville	12 B/10	1986	6th
Shag Island	12 B/15	1986	3rd
Mainland	12 B/11	1986	3rd
Anticosti Island			
Lac Faure	12 E/13	1977	2nd
Rivière au Fusil	12 E/12	1977	2nd
Anse de la Sauvagesse	12 E/14	1977	2nd
Port Menier	22 H/15 & H/16	1978	2nd
St. Lawrence Lowlands			
Lachine	31 H/5	1988	9th
Laval	31 H/12	1988	9th
Laurentides	31 H/13	1989	11th
Trois-Rivières	31 I/7	1981	7th
Sorel	31 I/3	1984	6th
Saint-Léonard-d'Aston	31 I/1	1987	8th
Grondines	31 I/9	1983	6th
Saint-Raymond	21 L/13	1983	4th
Portneuf	21 L/12	1981	6th
Verchères	31 H/14	1979	7th

APPENDIX 3-1



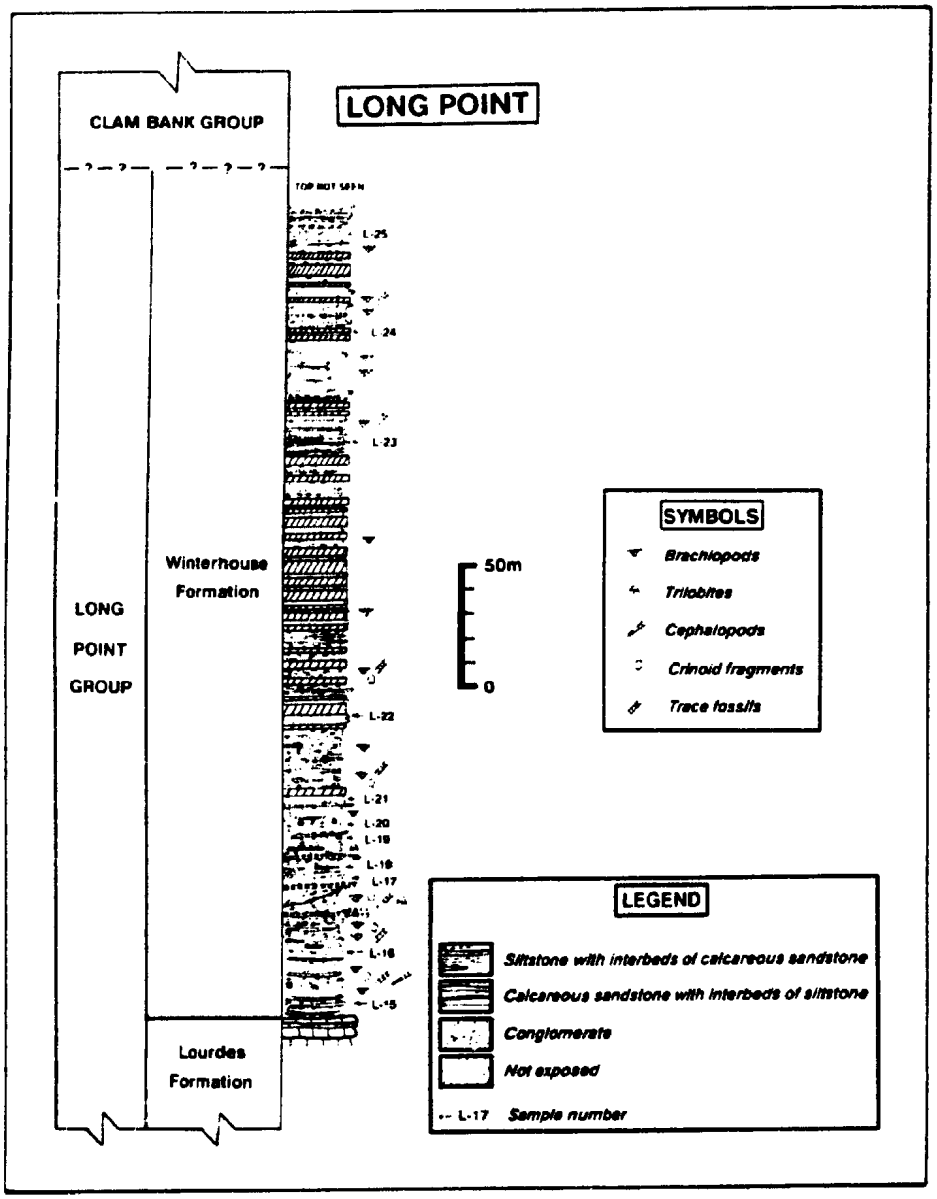
Geological log of the Table Head Group at Table Point, western Newfoundland, showing sampling horizons, (after Williams *et al.* 1987 and Stenzel *et al.* 1990).

APPENDIX 3-2



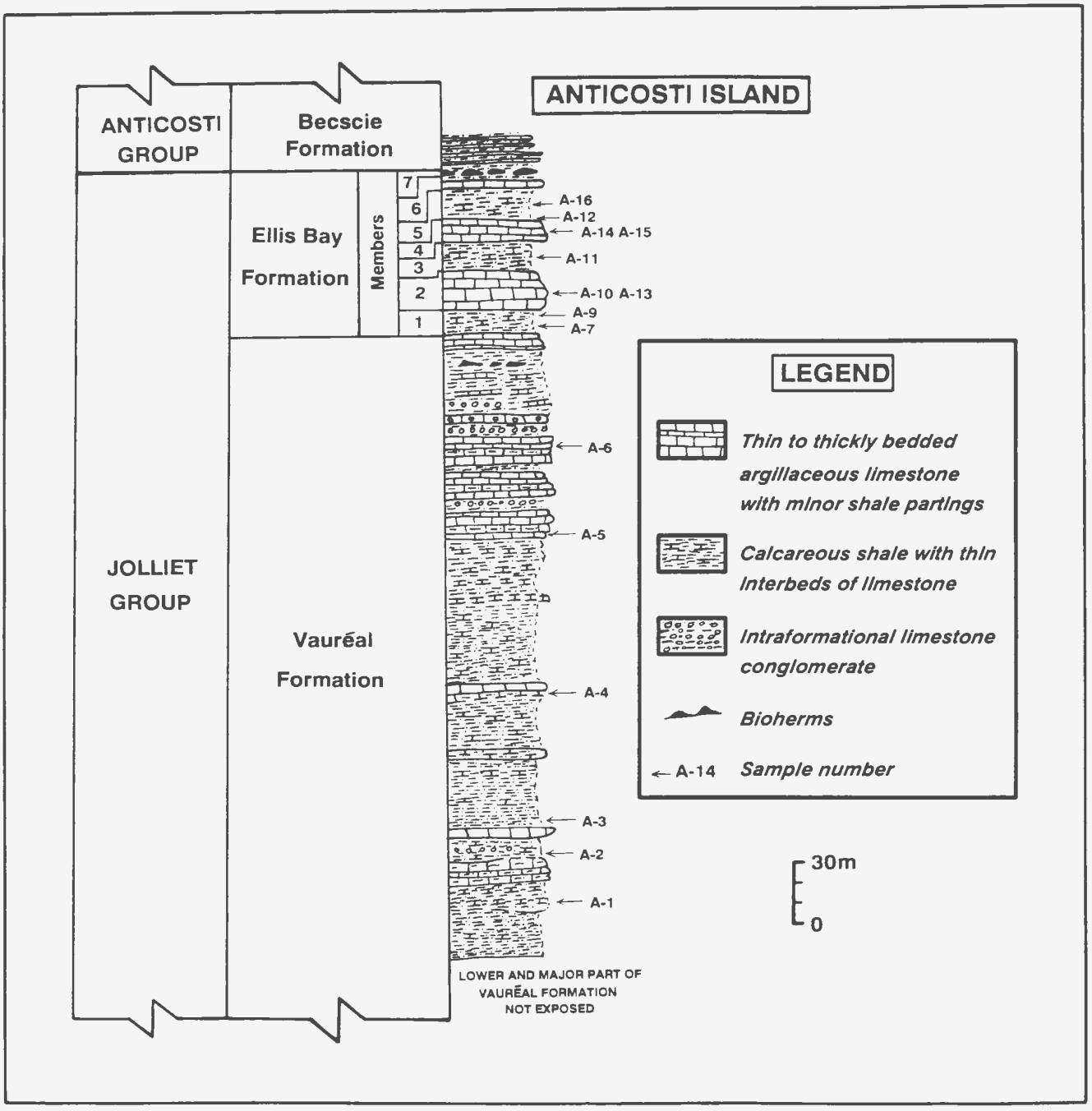
Geological log of the Lourdes Formation at Long Point, western Newfoundland, showing sampling horizons.

APPENDIX 3-3



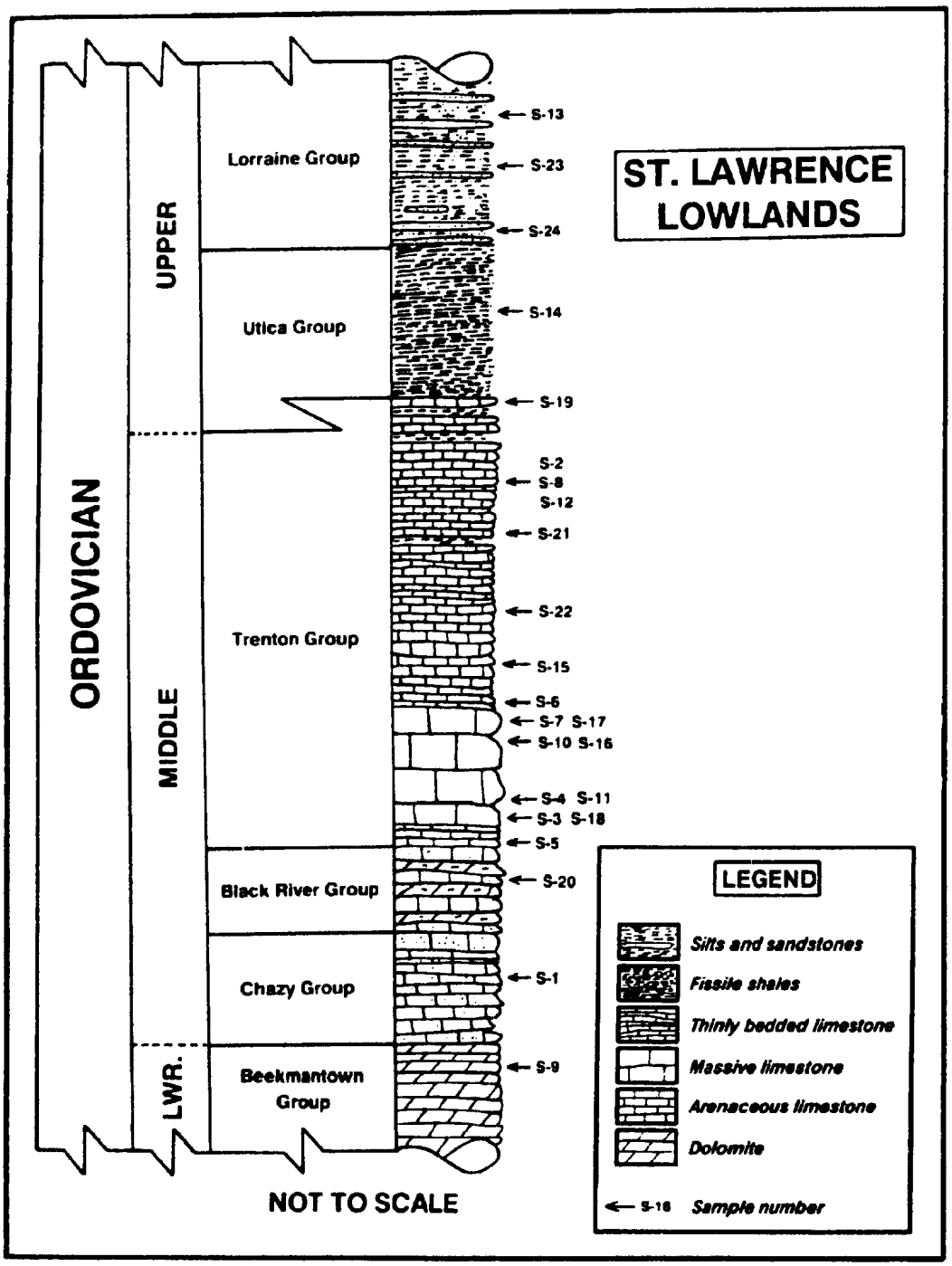
Geological log of the Winterhouse Formation, at Long Point, western Newfoundland, showing sampling horizons.

APPENDIX 3-4



Composite log of the Jolliet Group, Anticosti Island, showing sampling horizons, (after Bolton 1961 and Lespérance 1981a).

APPENDIX 3-5



Composite log of the Ordovician succession in the St. Lawrence Lowlands of Québec, showing sampling horizons, (after Globensky 1987 and Hofmann 1989).